MECHANICAL BIOLOGY

MECHANICAL BIOLOGY

Announcing the Discovery

of

Twelve Biological Rules or Laws

By

THE REV. P. H. FRANCIS, M.A.

London:
THE MITRE PRESS,
MITRE STREET, E.C.3.

Made and printed in Great Britain for THE MITRE PRESS (Fudge & Co., Ltd.),
London, by WARWICK PRINTING CO, LTD., 9, High St., Warwick.

PREFACE

BY studying mechanical implements with reference to the mechanisms of the human body, the author has been able to discover twelve biological Rules or Laws. These Rules allow the problems of the origins and developments of all types of mechanical implements to be solved. They also provide new methods of studying the mechanisms of the human body.

The discovery of the Rules or Laws must profoundly affect the studies of biology, anatomy, physiology, psychology, and similar branches of science, and in due time the practices of medicine and surgery.

Many people who find the present day sciences of biology and anatomy dull and difficult and regard them, because of lack of laws or rules, as little more than attempts at naming parts and actions of plants and creatures, will now find these sciences easy and full of interest; and many who have hitherto regarded museums as little more than places for exhibiting the discarded lumber of the past, will see that the study of weapons and other implements, when made with reference to mechanisms of the body, can give knowledge of the construction and working of the human body, and reveal the secrets of growth and life and death.

A new world of scientific knowledge is shown in this work. No more than a beginning has been made in exploring it; but it is hoped that it has been sufficiently mapped to allow others to continue its exploration.

The newly discovered Rules are stated on page 129.

CONTENTS

Part II
THE REPRODUCTIVE MACHINERY

Part III
THE LOCOMOTIVE MACHINERY

PART IV
THE MOTOR CAR

ILLUSTRATIONS

Figure		*Page*

INTRODUCTION

IT is generally agreed that many types of mechanical contrivances are similar to contrivances of the body. It is said, for example, by nearly every writer on the biology or anatomy of the body that an optical lens resembles the lens of the eye, that a camera is constructed on the same principles as the eye, that an electric cable resembles a nerve in many respects, that the actions of a common pump and of the heart of a creature have many correspondences, and so on. But, hitherto, no one it seems has made a study of this phenomenon with a view to discovering its significance. When such a study is made, the following facts, among many others, soon become apparent:—

1. Every mechanical contrivance corresponds to and is a copy of some contrivance of the body.

2. A useful mechanical contrivance cannot be made that is not a copy of a contrivance of the body.

3. No mechanical contrivance can work apart from its human counterpart.

4. A mechanical contrivance is an embryo of its human counterpart; and as it is developed corresponds more closely to it.

When a study is made of any type of mechanical instruments with reference to the human body, Rules can be obtained which help to show how mechanical contrivances originate and develop and are related to each other and to the body; and these Rules can also be used for discovering how the body itself is constructed and works.

The book is divided into four main parts. In the first part weapons are studied with reference to the body. A detailed study of weapons bound to or held in the hand allows Rules to be discovered. These are given in Chapter 14. Progress then becomes easier, and during the study of other types of weapons, the ways weapons originate and develop, and the

ways different types are related become known. Furthermore, and more important, the ways weapons will develop in the future become known.

During the study of weapons it becomes evident that when making weapons the reproductive machinery of the body is mechanized. This phenomenon is briefly studied in the second part of the work.

In the third part of the work some elementary types of locomotive contrivances are studied; and the origins of the wheel and of some other mechanical locomotive contrivances are discovered.

In the fourth part of the work, a study is made of the internal combustion engine with reference to the body. This study shows the mechanical engine is a type of creature, possessing a rudimentary type of heart, stomach, alimentary canal, a double system of nerves, and other organs and mechanisms corresponding to those of creatures. The study also shows that the engine has no organs that are not possessed by creatures. It appears that the engine is developing continually to reproduce more features of the bodies of creatures.

Among other important results obtained from a study of mechanical biology is a knowledge of the ways in which materials can be arranged to possess the property of life. The secret of organic life is being sought for in laboratories, for example by trying to make a living cell; but knowledge of this secret can easily be obtained, and perhaps can only be obtained, from a knowledge of mechanical biology. Mechanical biology also gives an understanding of the processes of organic growth. It also reveals the meaning of man's industrial career, and the goal of the makers of mechanical contrivances and machines.

Mechanical biology also provides an indirect but powerful means of obtaining knowledge of the construction and ways of working of the human body. This is so, because all mechanical instruments, contrivances, and machines, are elementary models of parts of the body. A direct study of the human body is immensely difficult; but by studying it

indirectly by studying the simple models of its various parts provided in such profusion by mechanical contrivances knowledge of the body can be easily obtained.

A new world of knowledge is made known by studying mechanical contrivances with reference to the body. This work does little more than point the way to this new world and shows but a few specimens of its treasures. The work of discovering its limits and exploring it fully will demand the time and efforts of a host of explorers.

Part I

WEAPONS

Chapter I

THE WEAPON AND THE WIELDER

A WEAPON is hand-made and could be reproduced if necessary, and therefore it might be thought that the natures of weapons are fully understood. But weapons are not fully understood, for many things about them remain to be discovered.

The maker of a weapon knows about the materials from which it is made, and how to fashion it from the materials, and the purpose of the weapon, and how to use it. But the weapon is made according to rules handed down, and the maker of a weapon is not always interested in the history of weapons or in theories of weapons. The rules by which weapons can be improved or new types made are not known to him; and improvement of a weapon or the production of a new type is usually the result of an accidental discovery or a process of trial and error. Weapons have been carefully studied, but the laws governing their developments remain undiscovered. The manners in which weapons evolve are not known, nor are the relationships between weapons of different types known. Attempts have been made to show that all types of weapons have been developed or have evolved from a few simple types like sticks and stones, but all such attempts have failed. The origins of some types of weapons are unknown. No one knows, for example, whether the bow and arrow was developed from some other weapon or was an independent "invention". Attempts have been made to classify weapons into types, but no system of classification has been quite satisfactory. The effects on the actions and movements of the body when weapons of different types are wielded or when weapons of the same type but of different shapes and sizes and weights are wielded have not been scientifically studied. Furthermore, until the present time, it has not been known that relationships exist between parts of a weapon and parts of the body.

It can therefore be seen that many things about weapons are still unknown, and that their natures are not fully understood.

It is easy to see that a weapon is related to the body of its wielder. The dimensions of a weapon must be related to the wielder; the length of a bow, for example, is related to the height of the archer, and indeed the long bow was supposed to be the same length as the height of the archer. The weight of a weapon must be suited to the wielder, a heavy shot or hammer, for example, is usually wielded by a heavy man and not by a light man. The power of a weapon must be proportioned to the power of the wielder; a bow made for a man, for example, is more powerful than one made for a woman or for a child. Each type of weapon requires its own special actions and movements from the machinery of the body of the wielder. The manner of wielding a javelin is different from the manner of wielding a discus, and the manner of wielding a discus is different from the manner of wielding a bow and arrow. The javelin is thrown in a certain way, the discus in another way, and the arrow from the bow in another way. Furthermore, different weapons of the same type require to be wielded in different ways. Even a slight alteration in the size or weight or shape of a weapon demands slightly different actions and movements from the machinery of the body. A light stone is thrown in one way and a heavy stone in another way. If stones of various sizes were to be thrown in succession, the missiles thrown being successively heavier, the actions and movements of the thrower would be noticed to change. A light stone would be thrown with a free and easy action with the fingers playing an important part in holding and releasing the stone. When a heavy stone was thrown, the actions of the thrower would be slower and more deliberate and the palm of the hand would play a more important part than the fingers in the throwing actions; and when a very heavy stone was thrown the actions of the shot putter would be seen. Similarly, if sticks of various sizes were to be thrown in succession, the missiles thrown being successively larger, the actions

and movements of the thrower would be noticed to change. A small and light stick would be thrown with a free and easy action with the fingers playing an important part in holding and releasing the stick. When a large and heavy stick was thrown, the actions of the thrower would be slower and more deliberate, and the palm of the hand would play a more important part than the fingers in the throwing actions; and when a very heavy stick, or the trunk of a tree, was thrown the actions of the caber tosser would be seen (*Figure 23*).

It is clear therefore that a weapon cannot be understood if it is studied without reference to the body of the wielder. Before a weapon can fulfil the purpose for which it was designed and made, it must be fitted to the body, and when it is so fitted it becomes part of the machinery of the body.

That a weapon becomes part of the machinery of the body of the wielder may appear at first to be a new and difficult conception. But it is not a new conception nor is it a difficult one for the mind to hold; for it is held, although perhaps unconsciously, by most people. A weapon has little or no meaning to the mind unless it is associated with a wielder, and usually when looking at a weapon a picture is formed in the mind of the weapon being used by a wielder. The artist and the sculptor accept as a first principle that the machinery of the body of the wielder and the weapon being wielded form a unity. An artist or a sculptor does not depict a weapon being wielded without taking into account the relationships between the weapon and the wielder, and always fits the weapon into the machinery of the body as correctly as possible. We should at once detect any gross error made by an artist or sculptor who failed to allow sufficiently for the length or weight of a weapon, or who failed correctly enough to relate the weapon to the actions and movements of the wielder.

To study the actions and movements of the body of the wielder and the weapon being wielded together is to combine methods used by students of weapons today and methods of study used by the ancient Greeks. The ancient Greeks studied the actions and movements of the wielders of

weapons closely, as is evident from the excellence of the statues they made of the wielders of weapons; but they made no serious study of the relationships between weapons of different types The modern student, on the other hand, makes a close study of the weapons and of the relationships between weapons of different types, but makes no serious study of the actions and movements of the wielders of the weapons. Neither the methods of the ancient Greeks nor the methods of the student of today have allowed much knowledge to be obtained of the machinery of the body of the wielder or of the weapons. The ancient Greeks did not discover the relationships between the actions and movements of the wielders of one type of weapon and those of the wielders of another type; and the modern student has not yet discovered the laws governing the relationships between weapons of different types, and has not yet any clear ideas of the ways in which types of weapons originate and evolve. But by combining the two diverse but complementary methods, as has been done in this work, knowledge can be obtained of the relationships between the actions and movements of the wielders of different types of weapons, and of the ways in which types of weapons originate and evolve.

CHAPTER 2.

THE FIST

WEAPONS can be formed by parts of the body. The hand can form a fist or claws for use against an opponent. The elbow or knee or foot or head can be used as a weapon. The whole body can be used as a weapon by being hurled against an opponent. But the hand is the part of the body which most often forms the offensive contrivance which is immediately used against an opponent, and the fist is the type of contrivance most often formed and used.

The fist is a very complex contrivance and has a very complicated structure. Some of its main features may be briefly noticed. Parts of the fist are formed by the main joints of the fingers, or parts of the fingers between the main and middle knuckles. Parts are formed by the middle joints, or parts of the fingers between the middle and top knuckles. Parts are formed by the top joints, or parts of the fingers between the top knuckles and finger tips. Parts are formed by the main and middle and top joints of the thumb. Parts are formed by the bones of the hand. Main knuckles are formed where the fingers are jointed to the hand; middle knuckles where the main and middle joints meet, and top knuckles where the middle and top joints meet. The knuckles are of different shapes and sizes, and each has its special place in the fist. The main finger joints are approximately parallel to each other; the middle joints to each other; and the finger ends to each other. The finger nails lie inside the fist and add to its strength.

The fist is not composed of the same materials throughout. Some parts are made of skin, others of bone or flesh or sinew or blood or other materials. Each part of the fist has its own part to play when a blow is being delivered, and the part each plays depends on the way the fist is being used. Certain knuckles play more prominent parts than others. The finger nails lying in the fist do not play prominent parts. The

thumb nail plays a more prominent part; but the opponent is usually hit by its surface, and its edge is little used.

When the fist is being used certain parts of the body perform certain actions. Knowledge of the parts directly used in the wielding of the fist and of their actions cannot easily be obtained by observation of anyone using the fist against an opponent, for the body is a very complex contrivance and its actions and movements when used against an opponent are very complicated. But some of the parts and their actions and movements can be noticed in a general way. The fist is the weapon formed by the body to inflict the blow; the weight of the blow depends partly on the weight of the fist; the arm is straightened to deliver the blow, and the weight of the arm contributes to the weight of the blow; the weight of the body steadies the body when the blow has been delivered; the legs are so placed at any time that balance shall be maintained; the movements of the left hand are related to those of the right hand; the movements of the feet are related to those of the hands.

The type of weapon formed by the fist depends partly on the way it is used. It forms one type of weapon when it is used to deliver a hammer blow; another type when it is used to deliver a swinging blow; another type when it is used to deliver an upper cut; another type when it is used to deliver a straight thrust; and so on. The type of weapon it forms depends also partly on the parts of the fist which come into contact with the opponent. It forms one type when a blow is delivered by the main knuckles; another when a blow is delivered by the middle knuckles; another when a blow is delivered by the top knuckle of the thumb; another when a blow is delivered by the second knuckle of the thumb; another when a blow is delivered by the lowest knuckle of the thumb; another when a blow is delivered by the flat of the fist; another when a blow is delivered by the side of the forefinger and thumb; another when a blow is delivered by the side of the hand and little finger; and so on. It also forms one type of weapon when one knuckle only hits the opponent; another when two knuckles and one thumb

knuckle hit the opponent; and so on. The type of weapon it forms also depends partly on the way the fist is clenched. Different types of weapons are formed when the thumb is placed over the forefinger and middle finger, and when it is placed at the side of the forefinger, and so on

The fist is held rigidly to the forearm. It is less tightly clenched when it is being wielded than when the blow is about to be delivered and when it is being delivered. When the blow is about to be delivered and when it is being delivered the hand is very tightly clenched; and the wrist is firmly set and the fist very rigidly connected to the forearm.

The movements of one fist are balanced by the movements of the other fist which is almost the same in size and shape and weight. The movements of the fists in the direction of the opponent are very similar but opposite. If one fist goes forward, the other comes back; if one ascends, the other descends, and so on. The movements of the fists round the body are very similar and in the same directions. If the body is turned to the right, both fists swing round to the right moving in approximately similar curves and through equal distances. Similarly, if the body is turned to the left, both fists swing round to the left moving in approximately similar curves and through equal distances. The movements of the fists on account of the raising or lowering of the body are similar and in the same directions. If the body is raised or lowered, both fists are raised or lowered equal distances each being raised or lowered a distance equal to the distance the body is raised or lowered. The movements of the fists and feet are related, but may be similar or opposite in directions. The right fist and right foot may be thrust forward or drawn back together, or the left fist and right foot may be thrust forward or drawn back together. When the fists are moved quickly the positions of the feet must be changed quickly to correspond. The direction of the blow is approximately the direction of the line joining the fists at the moment the blow is delivered; and the direction of the opponent at the moment the blow is delivered is approximately the direction of the line joining the feet.

The fist consists entirely of living organic parts. It is a weapon formed wholly by the hand, and the weapon used against the opponent has no artificial or mechanical parts. All the elements of which the hand is composed are however found in the organic materials of mechanical weapons, and some of the elements are found in their inorganic materials.

Knowledge of the features and structure of the fist and of its actions and of the actions and movements of the body when wielding a fist can however best be obtained indirectly by a study of various types of hand weapons. It will be shown that each part of a hand weapon is a copy of some part of the fist, and that the mechanical part is operated or wielded by the human part and is made to carry out actions against the opponent on behalf of the human part, the mechanical part acting as an agent of the human part for offensive purposes. Since each part of a hand weapon is a copy of a part of the fist examination of hand weapons and of their actions gives some knowledge of the fist and of its actions. No hand weapon reproduces more than a few of the parts of the fist, and usually a part of a weapon is a very imperfect reproduction of a part of the fist. Full knowledge of the fist and of its actions cannot therefore be obtained, but many things can be learnt about the fist and its actions, by examination of hand weapons and of their actions.

CHAPTER 3

THE ROUND STONE

PROPERTIES of the fist made use of in delivering a blow are its size, weight, and hardness. The mass of bones, sinews, veins, blood, etc., forms a fairly hard, roundish object to hit an opponent. But the fist is a delicate contrivance which can be easily damaged. The joints can be easily dislocated or the blood vessels burst or the skin broken. Almost any hard, roundish object of about the size of the fist would be preferable for wielding by the forearm if it could be made to take the place of the fist. But it is not possible to replace the fist without removing the hand; and removal of the hand is not desirable. No doubt, if any great advantage could be obtained for offensive purposes by removal of the hand and substitution of a hard, roundish object, the method would have been used at some time or another. But even if the desperate expedient of removing the hand were adopted, means of fastening the object to the forearm would have to be devised, and would be difficult to devise satisfactorily. The fist, however, can be partly replaced by means of certain types of weapons, so that a kind of fist partly human and partly artificial is formed, a human part being formed by the hand and an artificial part being formed by the weapon. Fastenings can also be formed by the hand and by the weapon to hold together the human and artificial parts of the fist.

Some understanding of the ways in which the hand and a weapon can together form a kind of fist, and of the ways in which the hand and a weapon can be held together, can be obtained by considering the way in which a spherical stone can be held and used to club an opponent.

The size of the spherical stone that can with greatest advantage be used to club an opponent is determined within close limits by the size of the hand. In order that the full power of the wielder may be applied, the stone must lie

within the hand against the palm. It is advisable that only the stone shall hit the opponent, and that the ends of the fingers shall not be sandwiched between the stone and the opponent. If a finger end is sandwiched, the force of the blow is softened for the opponent, and the finger end receives much of the force of the blow, and the result may be more painful and damaging to the wielder than to the opponent. As large a stone as possible must therefore be held so that the danger of sandwiching shall be as small as possible; but the stone must be small enough for the hand to enclose most of it, or it cannot be held and will fall from the grasp. The diameter of the largest spherical stone that can be effectively held by the hand is about half the span of the hand or rather less, the span being the distance between the tips of the thumb and little finger of the outstretched hand. The span of the hand varies with different hands, and therefore the size of the stone that can be wielded with most advantage varies with different hands.

The fastenings which hold the hand and stone together are formed partly by the hand and partly by the stone. The hand and fingers close partly round the stone which nearly fills the hand. The stone rests against the palm, and the tips of the fingers begin to close round the parts of the stone opposite the palm. The hand and fingers adapt themselves to the shape of the stone, and the flesh where it is in contact with the stone is deformed to take the shape of the stone. A pouch to hold the stone is formed by the hand and fingers which almost exactly fits the stone; and if the stone could be removed from the pouch without altering the shape of the pouch, it could be seen that the shape of the interior of the pouch reproduced very closely the shapes of the parts of the stone with which the hand and fingers had been in contact, and that the interior of the pouch formed parts of a sphere.

The interior of the pouch formed by the hand and fingers does not exactly reproduce the shapes of the parts of the stone with which it is in contact, because of the presence of creases on the insides of the hand and fingers. Three main creases are formed on the inside of each finger. The first is

formed at the inside of the top knuckle; the second at the inside of the middle knuckle; and the third where the finger meets the palm. When the hand is open and the fingers are stretched straight out, the creases on the fingers appear as separate transverse creases at the insides of the knuckles, but when the hand is closed they tend to come into three straight lines crossing the fingers. A crease is formed at the inside of the top knuckle of the thumb; and another at the inside of its second knuckle; another diagonally across the hand where the thumb is joined to the palm. Great numbers of smaller creases are also formed on the insides of the fingers and palm. The creases prevent an exact correspondence of the pouch and the surface of the stone; but act in much the same way as treads on vehicle tyres in giving a good grip. Furthermore, when the hand is open and the fingers are stretched out but closed, three grooves of irregular shapes are formed between the fingers. These grooves are very wide when the fingers are separated to hold a large stone; but act in much the same way as the grooves between the treads on vehicle tyres in helping to give a good grip.

Complementary parts of the fastenings to those formed by the hand to hold the hand and stone together are formed by the stone. The shape of the stone allows the tips of the fingers and thumb to begin to close round the stone. The stone conveniently fills the hand, which naturally takes a shape when nearly unclenched which would partly enclose a spherical object. The surface of the stone may provide a good gripping surface for the hand. Friction is called into play between the skin and the surface of the stone; and the amount of friction called into play depends on the materials of the stone and on the nature of its surface. When the stone is rough the amount of friction between the skin and surface of the stone is greater than when the stone is smoother; and a stone with a rough surface forms more of the fastenings to hold the hand and stone together than one which is smoother. The amount of friction called into play between the hand and the stone depends also partly on the pressures exerted by the fingers; and when the stone is rough, the

fingers need not press so firmly as when the stone is smoother. A rough stone therefore partly relieves the hand of the need for providing the fastenings to hold the hand and stone together, and the rougher the stone the more the hand is relieved of the need for providing some of the fastenings, but however good a grip is provided by the surface of the stone, the fingers cannot be relieved entirely of the need for exerting some pressure to hold the hand and stone together. The fastenings which hold the hand and stone together are therefore formed partly by the hand and partly by the stone. The parts formed by the hand and the parts formed by the stone are complementary, for the shape of the pouch is complementary to the shape of the stone, and the frictional devices provided by the hand are complementary to those provided by the stone.

The fingers hold the stone in a manner somewhat resembling the manner in which a spherical precious stone is held to its setting by metal claws. The finger ends which press on the surface of the stone opposite the palm are joined to the arm by means of the fingers and their connections within the hand and wrist and forearm. The fastenings for each finger end are separately formed as far as the web of the hand, but are joined within the hand and wrist and forearm. Just before delivery of a blow and while a blow is being delivered, the wrist is very firmly set, and the fastenings hold the stone very firmly, and the hand and stone and arm are very rigidly joined together.

The types of blows that can be given by the contrivance formed by the hand and stone are fewer in number than those that can be given by the unweighted fist. It is not desirable that the fingers shall come in contact with the opponent, and the opponent must be hit, if possible, only by the stone. The types of blows must therefore correspond approximately to those that can be given by the bare fist when the palm faces the opponent. A blow cannot be given by the back or side of the hand or the stone will be forced out of the hand. A hammer type of blow is the type that can most easily be given. An upper cut could be given; but the palm would

have to be held facing upwards, and the weight of the stone would act against the direction of the blow. A swinging blow could be given, but care would have to be taken to keep the palm facing the opponent so that the exposed surface of the stone would deliver the blow.

The hand and fingers when a spherical stone is being wielded are not required to come into contact with the opponent. The exposed surface of the stone hits the opponent, and releases the hand from the need for directly delivering the blow. The work of hitting the opponent is directly carried out by the stone, but of course indirectly by the hand which drives the stone against the opponent. The weight of the stone for descending types of blows is added to the weight of the hand; but the weight of the stone is of more immediate importance in giving weight to the blow than the weight of the hand. The stone therefore partly releases the hand from the work of directly providing the weight of the blow. Indirectly, of course, the hand provides the weight of the blow, for it raises the stone and assists its downward motion against the opponent.

The contrivance formed by the hand and stone like that formed by the unweighted fist is roundish in shape; but is larger than the unweighted fist. The main joints of the contrivance are not at right angles to the palm and parallel to each other as when the bare fist is used but fork straight out from the hand, and compared with their positions in the fist are turned nearly through a right angle. Each middle joint is bent through about forty five degrees from the line of the main joint; and each top finger joint is bent through about forty five degrees from the line of the middle joint so that it is approximately at right angles to the palm. The main knuckles are not prominently formed, and can hardly be distinguished from the back of the hand and main joints. The middle knuckles are much less prominently formed than in the fist. The top knuckles which are prominently formed but nearly hidden in the fist are not prominently formed in the contrivance but can be well seen. The finger nails which are hidden in the fist are visible in the contrivance. The

thumb is placed opposite the fingers and is about half unclenched. The surface of the stone forms a kind of artificial web between the fingers and between the fingers and thumb. The surface of the contrivance between the tips of the fingers and the thumb is formed by the stone, and is part of a sphere. The back of the hand and wrist of the contrivance are very similar to the back of the hand and wrist of the fist.

The contrivance consists of two main parts. A human part is formed by the hand, and an artificial part is formed by the stone. The hand forms the outer part, and the stone the inner part of the contrivance. The contrivance is fairly rigid, and the hand and stone move together in all movements and cannot have independent movements. The fingers cannot be separately manipulated, and retain the same relative positions to each other throughout all movements. The contrivance is firmly joined to the arm. The movements of the stone and hand are stopped at the moment the blow is given, and the movements of the arm are also stopped at the same moment.

The form of the hand can be obtained approximately from the form of the bare fist by gradually unclenching the hand until the fingers form claws as if for use against an opponent. The interior of the hand when it is unclenched to the position of forming claws approximately forms parts of the surface of a sphere. The form of the hand when wielding the stone is kept by the stone.

Certain advantages are gained by partly replacing the fist by a stone. A heavier and harder blow can be given. If the blow is given by the stone the hand is saved from damage. The range of the wielder when a stone is held is slightly greater than when the bare fist is used. But the advantages are accompanied by disadvantages. In order to avoid sandwiching the fingers, the contrivance must be carefully directed so that the stone hits the opponent. Considerable strain is placed on the fingers in holding the stone. The wrist has the work of wielding both the hand and stone, and a firmly set wrist is not so easily formed. The forearm cannot move the hand and stone as easily as the fist; and the movements of

the body are slowed down, and the opponent can more easily see the preparations for a blow and avoid the blow than when the bare fist is the weapon. The balance of the body is upset, because the unweighted hand cannot so easily balance the hand and stone, and the body must lean away from the stone to help to balance the stone. The guard is less effective, for the arm is raised for a longer period than when the fist is used, and the user can be more easily attacked.

Further knowledge of the ways in which the hand and a stone can together form an offensive contrivance and fastenings to join the hand and stone can be obtained by studying the form of the contrivance when the stone is approximately spherical and possesses small projections and indentations on its surface.

When a roundish stone possessing small projections and indentations is held, the relationships between the hand and stone are slightly different from those between the hand and a spherical stone. The projections and indentations help to release the hand from the need for forming fastenings, for they provide catches which assist in fastening the hand and stone together. The hand can immediately form a close fitting pouch for the stone because of its peculiar construction and the soft linings of flesh on the insides of the hand and fingers. The fingers are separate and can bend independently to fit into indentations and grooves. The fingers and hand tend to slip into the indentations and avoid the projections. The flesh is deformable and can fill small indentations and partly surround small projections. It presses into the indentations and takes their forms, and the projections press into the flesh and impress their forms on it. The hand and fingers form a pouch whose interior corresponds closely in shape to the shape of the parts of the stone with which it is in contact, and the hand and stone are then firmly fastened together. If the stone could be removed from the pouch without altering the form of the pouch, the shape of the parts of the stone with which the hand and fingers had

been in contact could be seen on the interior of the pouch.

The creases of the fingers and the grooves between the fingers play less prominent parts in holding the hand and stone together when the stone is irregular in shape and has projections and indentations than when the stone is spherical, in the same way as the treads on vehicle tyres play less prominent parts in holding the tyres to a surface when the surface is rough or broken.

The claws formed by the hand and fingers are more deformed than when the surface is spherical, for the finger ends press into indentations of different depths; or some may lie over projections and some in indentations. The shapes of the claws may then be more like the shapes of claws holding an irregularly shaped precious stone to its setting. The fastenings extend within the hand to the wrist and forearm; but each fastening is slightly modified in shape and position compared with its form when holding a spherical stone, and each exerts a slightly different pressure from the pressure it would exert if it held a spherical stone.

The types of weapons that can be formed when an irregularly shaped stone is wielded are more various than when a spherical stone is wielded; and depend partly on the particular projections which come into contact with the opponent, and on the shapes and positions of the projections, and on the way the contrivance is wielded. One type of weapon is formed when one projection hits the opponent; another when a different projection hits the opponent; and so on. One type of weapon is formed when one projection hits the opponent; another when two projections hit the opponent; another when three projections hit the opponent; and so on. One type of weapon is formed when a sharp projection hits the opponent; another when a blunt projection hits the opponent; and so on. One type of weapon is formed when a slashing blow is given by a projection; another when the same projection is thrust at an opponent; and so on. All types of blows or thrusts, however, must be given by the contrivance with the palm facing the opponent. Blows with

the side or back of the hand or by the fingers or thumb cannot easily or safely be given. Many of the types of blows that can be given by the bare fist therefore cannot be given by the contrivance.

Certain advantages are gained through the presence of projections on the stone. Sharper blows can be given, and the opponent can be more easily damaged. But the advantages are accompanied by disadvantages. The stone must not possess sharp projections on the parts in contact with the hand and fingers, and must be placed in the hand so that its projections face the opponent. It cannot therefore be fitted to the hand quite as quickly or easily as a spherical stone. Leverage may be exerted on the contrivance when the opponent is hit by a projection which may place additional strain on the fingers and wrist. Although the irregular surface may allow the stone to provide more of the fastenings, the pouch may fit less closely in certain places and may be less easily and quickly formed than when a spherical stone is held.

* * * * *

The above brief study of the ways in which the hand and a stone together can form an offensive contrivance, and the hand and stone can together form fastenings to hold the hand and stone together, reveals several important facts, among which are the following:—

1. The stone by itself is an incomplete weapon: the complete weapon is formed by the hand and stone together.

2. The contrivance formed by the hand and stone has many features of the fist.

3. The contrivance consists of two main parts: a human part formed by the hand, and a mechanical part formed by the stone.

4. The forms of the hand and stone are complementary.

5. The contrivance is wielded in much the same way as the fist.

6. The hand is released by the stone from the need for directly delivering the blow.

7. The type of weapon formed by the hand and stone depends on the way the contrivance is used and on the parts which come into contact with the opponent.

8. The fastenings which hold the hand and stone together are formed partly by the hand and partly by the stone.

9. The human and the mechanical parts of the fastenings holding the hand and stone together are complementary.

10. The contrivance is held to the arm by fastenings formed by the fingers and their connections to the arm.

11. All actions and movements of the body are affected by the partial replacement of the fist by a stone.

12. Advantages gained by partly replacing the fist are accompanied by disadvantages.

CHAPTER 4

THE EARLY GREEK CAESTUS

IN early Greek times a hand weapon was formed by winding a thong of soft leather round the hand and forearm. The weapon which was a type of caestus formed a kind of boxing glove and was used in boxing contests. *

The thong of the early Greek caestus was between ten and twelve feet in length; and the main part of the caestus was formed by winding the thong round the parts of the hand between the fork of the thumb and the middle knuckles of the fingers. The two top joints of the four fingers were uncovered and were bent until the ends of the fingers rested on top of the caestus. The thumb which was usually uncovered rested against the side of the caestus. Parts of the thong were wound round the wrist and forearm.

A little study soon shows that the caestus made from a thong can be made of a certain size and shape but of no other size and shape; and that its size and shape are determined by the size and shape of the hand. It does not form a complete weapon by itself. Complementary parts are formed by the hand; and the hand and caestus together form the complete weapon.

The caestus provides a means of increasing the weight of the blow, for the weight of the caestus is added to the weight of the hand. It might seem that the size of the caestus and therefore the weight of the blow could be easily increased by winding more turns of the thong round the hand; but the number of turns of the thong must not be so many that the thumb is forced outwards to any appreciable extent, or the thumb may be sprained if it comes in contact with the

* For descriptions and illustrations of the caestus see:— H. S. Cowper, F.S.A., *The Art of Attack;* E. Norman Gardiner, M.A., D.LITT., *Greek Athletic Sports and Festivals, Athletics of the Ancient World;* W. W. Hyde, *Olympic Victor Monuments;* Sir W. Smith, LL.D., *Dictionary of Greek and Roman Antiquities;* etc.

opponent. The caestus must just reach to the thumb and allow it to rest in a natural and easy position against the side of the caestus. The breadth of the caestus is therefore closely determined by the size and shape of the hand on which it is wound.

The width of the part of the caestus wound round the hand, measured from the fork of the thumb to the middle knuckle of the forefinger, is determined by the distance between the fork of the thumb and the middle knuckle of the forefinger. The thong must not be wound round the middle knuckles of the fingers or the two top joints will not be able to bend and press on the top of the caestus to help to hold the caestus to the hand. It must not be wound deeply into the fork of the thumb or the thumb may be constricted.

The thong cannot be wound round the two top joints of the fingers. If it were wound round the two top joints, the fingers would be forced to a point; and a blow given by the points of the fingers with the weight of the hand and caestus behind it might be more painful to the giver of the blow than to the receiver, and might result in dislocation of the finger joints. Also the caestus would be more liable to slip off the hand if it were wound round the ends of the fingers.

The two top joints of the fingers must be bent so that the ends of the fingers lie on the top of the caestus and keep the shape of the hand and the shape of the caestus. If the two top joints are not bent, the thong will draw the main knuckles of the forefinger and little finger towards each other so that a hollow is formed in the palm; but if the two top joints are bent, a strong, flattish surface is formed by the palm and main joints of the fingers which can resist the pressure exerted by the thong to draw the sides of the hand together.

The width of the caestus therefore must be rather less than the distance between the fork of the thumb and the middle knuckle of the forefinger. The width varies slightly with different hands; and a large hand requires a slightly wider caestus than a small hand.

The size and shape of the parts of the caestus wound round the hand are therefore determined within close limits

by the size and shape and form of the hand, and the form of the caestus must be complementary to the form of the hand.

It is clear that before winding the thong a strong, flattish surface must be formed by the main joints and palm. The thong must not be wound so closely into the fork of the thumb that the thumb is constricted, nor so closely to the middle knuckles that the middle joints cannot be bent at right angles to the palm and the finger ends be bent downwards so that they are about on a level with the top of the thumb. The thumb must be straightened and be moved outwards while the thong is being wound round the hand, and when the thong has been wound must be able to resume its position and lie easily and comfortably against the side of the caestus. The thong must not be wound round the hand so tightly that the fingers are constricted, and they must be free to straighten or bend at will. The parts of the thong which are not wound round the hand are wound round the wrist and forearm, and help to hold the caestus to the arm and act as supports for the wrist.

The fastenings which hold the hand and caestus together are formed partly by the hand and partly by the caestus; and the parts of the fastenings formed by the hand are complementary to those formed by the caestus. The main part of the caestus forms a clasp which fits closely round the hand. The parts wound round the wrist and forearm are so shaped that they form clasps which fit closely to hold themselves to the hand and the main parts of the caestus to the hand and wrist and forearm. The ends of the fingers press on the top of the caestus and act as a catch to prevent it slipping off the hand. The fork of the thumb acts as a catch to prevent the caestus slipping up the hand. The part of the caestus round the hand can be deformed to some extent by the pressure of the hand, and comes partly to the shape of the hand; but it forms a fairly solid band, and cannot be much deformed. The flesh of the hand however is much softer and can be more easily deformed and comes easily to the shape of the inner

surface of the band, and thus a fairly close and accurate fit of the hand and main finger joints and inner surface of the band is obtained. The ends of the fingers press on the top of the caestus and are slightly flattened, and take the shape of the parts of the top of the caestus with which they are in contact. The parts of the thong round the wrist and forearm take the shape of the parts of the wrist and forearm with which they are in contact. The flesh of the wrist and forearm is soft and allows the thong to form grooves in which to lie; and the flesh rises partly round the sides of the thong and prevents it slipping sideways. The flesh is softer than the leather and adapts itself easily to form complementary parts of the fastenings formed by the inner surfaces of the thong. The fastenings formed by the hand and by the caestus could easily be seen to be complementary if the hand and caestus could be separated without altering their forms. The parts of the hand and parts of the caestus which had been in contact would be seen to correspond almost exactly.

The various creases of the fingers and palm and the grooves between the fingers play small but important parts in holding the hand and caestus together. Grooves are also formed by the turns of the caestus, and the parts of the grooves in contact with the hand and fingers act in much the same way as treads on vehicle tyres in helping to give a good grip, and the flesh is forced up into the grooves. The grooves formed by the turns of the thong wound round the wrist and forearm also act in much the same way as treads on vehicle tyres in helping to give a good grip. If the thong is wound three times round the wrist and forearm, the turns lie next to and parallel to each other, and two grooves are formed, and the flesh is forced up into the grooves. If the thong is wound twice round, one groove is formed; if four times, three grooves are formed.

The fastenings holding the hand and caestus together are in two main parts. Human parts are formed by the hand and artificial parts by the caestus. The hand is partly released from the need for forming fastenings by the fastenings formed by the caestus. The hand need consciously exert

little pressure to hold the caestus, for the thong is wound fairly tightly and exerts pressure to hold the hand and caestus together. The pressure exerted by the caestus depends on the way the caestus is wound. The thong must be wound tightly enough to hold itself firmly to the hand; but must not unduly constrict the hand. To obtain the right pressure is a matter of experience. The tightness of the first turns round the hand especially must be carefully adjusted, for each turn made over turns already made increases the pressure.

The thong is made from ox-hide, raw or dressed with oil or fat to render it more supple, and conforms easily to the shape of the hand and wrist and forearm. Turns made round the hand above those already made unite firmly with those below so that a fairly solid mass is formed round the hand. The thong must be soft and supple and its nature as nearly as possible the same as that of the skin and flesh so that it may fit the hand and wrist and forearm closely and form a close union with the parts with which it is in contact. It must also form padding to protect the hand from the jar of the blow. The thong as it forms a solid mass round the hand forms padding on the inner surface of the mass against the hand, and the parts of the thong round the wrist and forearm also form their own padding for the wrist and forearm. The heat of the hand is preserved, and is not carried away as it would be if the caestus were made of metal or some other heat conducting substance or as it is carried away when a stone is held; but the thong is not as porous as the skin, and air and moisture cannot pass easily directly through the thong from the hand, and ventilation must be effected by air escaping and being drawn in between the hand and the top and bottom of the caestus.

The fist is held to the arm by complicated fastenings formed by the skin, sinews, bones, etc., of the hand and wrist and forearm. The main part of the caestus is held to the arm partly by human fastenings and partly by artificial fastenings. The finger ends which press on the top of the caestus are held to the arm by fastenings formed by the fingers and their connections within the hand and wrist and

forearm. The fastenings for each finger end are separately formed from the end of the finger to the web of the hand, but within the hand and wrist and forearm are connected to the fastenings joining the other finger ends. The skin forms part of the fastenings which hold the main part of the caestus to the arm, for friction holds the caestus to the skin, and the skin of the lower part of the hand and of the wrist and forearm tightens if the caestus begins to move off the hand and helps to prevent further movement off the hand. The main part of the caestus is also held to the arm by the parts of the thong wound round the lower part of the hand and round the wrist and forearm. The thong cannot hold the caestus firmly to the arm without the help of the human fastenings, and the fingers and skin cannot hold the caestus to the arm without the help of the thong. Both the human and the artificial fastenings are needed to hold the main part of the caestus to the arm.

The hand itself is held to the arm not only by human fastenings formed by the skin and parts within the hand and arm, but also partly by the artificial fastenings formed by the parts of the thong round the wrist and forearm. If the main part of the caestus begins to move off the hand, it tends to pull the hand away from the arm. It is fastened by pressure to the skin which begins to move with the caestus away from the arm and off the hand. Much movement of the ring and skin is however prevented partly by the tightening of the skin and partly by the tightening of the parts of the thong round the wrist and forearm which therefore help to hold the hand to the arm.

The fastenings formed by the caestus to hold itself to the arm partly replace the human fastenings in the work of holding the caestus and hand to the arm. The parts of the thong connecting the caestus to the arm carry out part of the work of holding the caestus to the arm, and partly relieve the human fastenings connecting the finger ends to the arm of this work. The finger ends would need to exert much pressure on the caestus at certain times to prevent it slipping off the hand, and the human fastenings connecting

the finger ends to the arm would be under considerable strain if the work of preventing the caestus slipping off were not partly carried out by the parts of the thong connecting the main part of the caestus to the arm. The actions of the human and artificial fastenings are complementary; for if the tensions of the human fastenings connecting the finger ends to the arm are decreased or increased, the tensions of the artificial fastenings connecting the main part of the caestus to the arm are correspondingly increased or decreased. The parts of the thong connecting the caestus to the arm must be so tightened that their tensions are sufficient to relieve the human fastenings of any need for exerting undue tensions and being strained, but must not be tightened so much that the caestus is drawn against the fork of the thumb. The skin is partly replaced by the thong in the work of holding the caestus to the arm, for movement of the caestus off the hand is partly prevented by the thong, and the skin need not tighten so much to hold the caestus to the arm as if no thong were used.

The parts of the thong round the wrist and forearm partly replace the human fastenings in the work of holding the hand to the arm. If parts of the thong were not wound round the wrist and forearm and the main part of the caestus began to move off the hand and its momentum relative to the hand was great, the skin as it was dragged with the caestus might be strained or torn or chafed, and the other fastenings within the hand and arm holding the hand to the arm might also be strained or torn. The skin and the other fastenings within the hand are not strong enough by themselves to check the momentum of the caestus suddenly if it is moving with much velocity without injuring themselves, and the work of checking the momentum of the caestus must be partly carried out by the artificial fastenings formed by the parts of the thong round the wrist and forearm which partly replace the human fastenings.

Movement of the caestus up the hand towards and against the fork of the thumb is partly prevented through the parts of the caestus round the main joints being of slightly smaller

sectional area than the parts round the main knuckles. The sections of the interior of the caestus taken at right angles to the palm and direction of the arm are approximately elliptical or oval; and are largest near the main knuckles and decrease slightly in size as they are farther removed from the knuckles. Because they are largest round the knuckles and decrease in size with distance from the knuckles, movement of the caestus up or down the hand is partly prevented. The smaller size of the part above the main knuckles would not be sufficient to prevent the caestus being pushed towards the fork of the thumb if a blow were given by the top of the caestus at the back of the hand. Tightening of the skin helps to prevent movement towards the fork, but frictional forces would not assist sufficiently to prevent movement and the skin might be strained or chafed if movement relatively to the skin took place. Movement towards the fork of the thumb is probably mainly prevented by the plaiting of the thong between the finger joints. It appears that while being wound the thong is passed three times between the main joints, once between the forefinger and middle finger joints, once between the middle and third finger joints, and once between the third and little finger joints. It is not certain that the thongs were plaited between the finger joints in this manner; but it is difficult to see that any other means could be used to prevent movement up the hand.*

The contrivance formed by the hand and wrist and forearm and caestus bears many resemblances to a fist and wrist and forearm. The middle knuckles and joints of the contrivance are little different in forms from the forms of the middle knuckles and joints of the fist, but their positions are modified. The top knuckles and joints of the contrivance are more clearly seen than the top knuckles and joints of the fist. The finger nails are visible and are not hidden as the finger nails of the fist are hidden. The thumb is placed on the side of the caestus in much the same way as it is placed on the side of the fist. The lower part of the contrivance

*Pausanias says that the thongs were plaited, but does not describe the method.

near the wrist is very similar in shape to the corresponding part of the fist. The main knuckles and parts near the main knuckles of the contrivance are artificial, and are formed by the main parts of the caestus whose form is largely determined by the shape of the main knuckles and parts near the main knuckles of the hand. The fastenings which connect the fist to the arm, except for the parts formed by the skin, are within the hand and wrist and are not visible; but the artificial parts of the contrivance connecting it to the arm are outside the hand and are visible. The contrivance formed by the hand and parts of the thong wound round the hand is larger than the bare fist; and is heavier by an amount equal to the weight of the parts of the thong wound round the hand.

The form of the hand holding the caestus can be obtained from the bare fist by unclenching the hand until the palm and lower joints of the fingers form a flattish surface. The middle joints are approximately at right angles to the main joints as they are in the fist. The main knuckles of the hand are not prominently formed but lie in the flattish surface formed by the back of the hand and the main joints; but the other knuckles are well formed, and are little different from their forms when in the fist. The main knuckles of the hand need not be prominently formed because they are partly replaced by the prominent artificial knuckles formed by the main part of the caestus.

The contrivance formed by the hand and caestus is in two main parts. A human part is formed by the hand, and an artificial or mechanical part is formed by the caestus. The hollow of the hand between the tips of the fingers and the palm is nearly filled by the caestus, and the part of the caestus within the hand forms the core of the contrivance. The contrivance is fairly rigid; and the hand and caestus cannot have independent motions, but move together in all movements as a unit. The human parts of the contrivance are formed of living organic materials; but the artificial parts are formed of lifeless organic materials. The materials and the structure of the materials of the thong however are

similar to the materials and structure of the materials of some of the human parts of the contrivance, and especially to the materials and structure of the materials of the skin and flesh of the skin. The parts of the thong connecting the ring, or band, of the caestus to the arm indeed are very similar in materials and structure of the materials to the parts of the skin and flesh of the skin over which they lie, and the inner surface of the ring is very similar in materials and in the structure of the materials to the materials and structure of the materials of the skin and flesh over which it lies. The contrivance does not possess any inorganic parts, unless the oil with which the thong is dressed is mineral oil. If the thong is dressed with animal fat or vegetable oil, it may possess more materials resembling those of the hand.

The caestus by itself is not a weapon. It cannot be formed without the hand which gives it its shape and keeps it in shape. It has no life of its own and no powers of acting against an opponent, and each of its parts must be moved against the opponent by its human counterpart. No part of the caestus is complete without its human counterpart; and the caestus does not possess any part which does not correspond to some part of the offensive contrivance formed by the hand. The form of the caestus is complementary to the form of the hand; and the caestus and hand fit almost exactly and together form a complete weapon. All parts of the caestus are correlated to all parts of the offensive contrivance formed by the caestus and hand, and to all parts of the machinery of the body which wield the contrivance. The fitting of the caestus affects all the actions and movements of the body; and the actions and movements of the wielder of a caestus are slower and more deliberate than those of the wielder of a fist.

The opponent may be hit by the caestus only, or by the fingers only, or by the thumb only, or by the caestus and fingers, or by the caestus and thumb. There is less danger of damaging the fingers through sandwiching than when the hand wields a spherical stone because the caestus is of softer materials than the stone; but damage to the thumb or finger

joints is more likely than when the bare fist is used if the thumb hits the opponent or the fingers hit the opponent, because the weight of the caestus as well as the weight of the hand is behind the blow. A straight blow delivered by the middle knuckles of the fingers would place much strain on the main joints and on the main knuckles of the fingers, because the main joints are in line with the palm, and the full force of the blow would be taken by the main knuckle joints. Although it is not easy to know how the contrivance was used by the ancient Greeks it seems probable that it was used so that preferably the caestus and not the fingers or thumb would deliver the blow and therefore that the types of blows usually delivered would correspond to those delivered by the main knuckles or sides of the bare fist. The types of blows usually delivered by the contrivance would therefore be fewer in number than those that could be delivered by the bare fist; but most of the types that can be delivered by the bare fist could be delivered in modified forms by the contrivance. The types of blows delivered by the caestus would not quite correspond to the types that could be delivered by the main knuckles and sides of the bare fist, because the main knuckles and sides of the fist are not very well reproduced in artificial forms by the ring of the caestus.

The ring of the caestus covers the main knuckles and the lower parts of the main finger joints and the part of the hand just below the main knuckles; and protects these parts, and releases them from the work of coming into contact with the opponent and directly delivering the blow. The blow given by the caestus, however, is indirectly given by the parts covered by the caestus, for the caestus is driven against the opponent by the parts of the hand immediately behind the part of the caestus which delivers the blow. The part of the caestus which hits the opponent therefore partly replaces the parts of the hand immediately behind it and partly releases them from their work of delivering the blow.

Certain advantages are gained by partly replacing the fist by a caestus. Parts of the hand are protected and saved

from possible damage and from the need for coming into contact with the opponent, and a heavier blow can be delivered by the hand and caestus than by the bare fist. The advantages however are accompanied by disadvantages. Likelihood of damage to the exposed parts of the hand is increased if they are allowed to deliver the blow. Damage to the main joints is more likely if a blow is given by the middle joints of the fingers. The wrist has more difficulty in keeping firm and holding the weapon firmly to the forearm although it is partly supported by the parts of the thong wound round the wrist and forearm; and it cannot be much helped, because of the danger of constricting the wrist if the thong is wound too tightly. The forearm must wield a heavier weapon, and its movements cannot be so quickly carried out. The actions and movements of the body are slowed down because of the weight of the caestus, and the opponent can more easily see the preparations for the blow and avoid it than when the fist is the weapon. The hand and caestus cannot be brought into action as quickly as the fist. A long time is required to make the thong, and some time is required to fit it to the hand; the bare fist, however, requires no artificial parts, and can be formed almost at once.

CHAPTER 5

THE LATER GREEK CAESTUS

ACCORDING to W. W. Hyde, the soft thong wound round the hand was used not to deaden the blow but to increase its force.[1] It is sometimes assumed that the early type of caestus formed from a thong of soft leather was used from a humane desire not to injure the opponent. The size and shape and weight of the caestus however are determined within close limits by the size and shape and form of the hand, and a caestus made from a thong cannot be made larger or heavier than it was made by the ancient Greeks. The thong of the caestus also must be made of soft pliable material because of the need for providing padding for the hand, and flexible fastenings to connect the caestus to the arm, and the early type of caestus cannot be made harder or sharper than it was made by the ancient Greeks. The ancient Greeks spared their boxing opponents because they were unable to make their caestus a more damaging weapon. We may however credit them with being sufficiently interested in the science of boxing to use a weapon with which some of the finer points of boxing could be demonstrated, and with being willing and patient enough to sacrifice the natural desire to obtain as soon as possible a weapon with which the boxer could deliver more damaging blows.

A type of caestus was later evolved by the Greeks which can inflict more damaging blows than can be given by a caestus formed by a thong of soft leather. But the advantages given by its use are accompanied by some serious disadvantages, some of them being that it is more difficult to make and to fit and is more cumbersome and less easily wielded than the earlier caestus.

The main features of the later Greek caestus are a glove,

[1] *Olympic Victor Monuments*; also E. N. Gardiner, M.A., D.LITT., *Greek Athletic Sports and Festivals.*

a ring of hard leather round the hand of the glove, and straps or thongs holding the ring to the glove, *Figure 1.* The ring consists of from three to five bands of hard leather of nearly equal sizes and shapes, the bands having sharp edges, and being held together by clasps. The glove is padded and fits closely to the hand and extends well down the forearm and sometimes ends in a rim of fleece. It has no finger ends, and the two top joints of the fingers are uncovered.

Fig. 1.
BACK OF RIGHT HAND OF MARBLE STATUE OF BOXER, FROM SORRENTO
Museo Nazionale di Napoli
(From a photograph)

An obvious method of making the caestus a more damaging weapon would seem to be by replacing the part of the caestus round the hand by a heavy metal ring or band. Such a method must almost certainly have suggested itself to the Greeks, but it can be easily seen that a heavy metal ring round the hand would be likely to be more dangerous and perilous to the wielder than to the opponent, and could not successfully be used to replace parts of the fist. If the parts of the hand and fingers between the fork of the thumb and the middle knuckles of the fingers were to be surrounded by a band of metal of a breadth to reach the thumb, a very damaging blow could be given; but if the fingers or thumb of the wielder hit the opponent as would probably happen during a boxing contest, the fingers or the thumb would be sandwiched between the ring and the opponent and would receive much of the force of the blow. If the opponent was hit by the part of the ring

at the back or side of the hand, the hand would be hurt by being suddenly stopped against the inner surface of the ring. To minimize the possible or probable hurt from sandwiching or from the hand being suddenly stopped against the inside of the ring, the outside parts of the surface of the ring opposite the finger ends and thumb could be padded and the inner surface of the ring could be padded; but the padding would have to be thick, and the size of the ring would have to be reduced considerably to allow room for the padding. To fasten the paddings in the right places would be a difficult matter. To prevent the ring being driven against the fork of the thumb would be difficult, and to prevent movement off the hand very strong fastenings would have to be provided to hold the ring to the arm and would be difficult to devise without constricting the wrist.

It can be seen therefore that a heavy metal ring could not easily or perhaps satisfactorily be made to replace parts of the fist. But the Greeks managed to replace parts of the fist with some degree of success by means of a ring of hard leather.

The manner in which the Greeks tried to solve the problems of fastening the hand and ring of hard leather together can be fairly well understood from an examination of the seated boxer of the Terme in Rome or of the boxer from Sorrento in Naples. A glove covers the main joints of the fingers and the hand and wrist and part of the forearm. The two top joints of the fingers are not covered by the glove, but are exposed and free. The glove is padded, and the padding is especially thick just below the ring to prevent the ring slipping up or being driven up into the fork of the thumb. The glove ends in a thick fleece of wool round the forearm. The ring is formed from three bands of hard leather of nearly similar shapes and sizes set one above the other and held together by clasps. Straps or thongs hold the ring to the parts of the glove round the wrist and forearm.

The size and shape of the ring are closely related to the size and shape of the hand. The breadth of the ring near the thumb is decided by the condition that the thumb must

not be forced outwards to any appreciable extent. The breadth of the ring at any other place cannot be much greater than near the thumb or the balance of the ring will be upset, and the leverage on the ring may be so great that very strong fastenings will be required to hold it to the glove. The width of the ring must be rather less than the distance between the fork of the thumb and the middle knuckle of the forefinger. The interior of the ring must be large enough to allow for the glove and padding as well as for the hand. The shape of the inner surface of the ring is determined indirectly by the shape of the hand. If the ring fitted immediately round the hand without a glove, its inner surface would be approximately elliptical or oval in section. But when a glove and padding are placed round the hand the inner surface of the ring is slightly less elliptical and slightly more circular in section.

The size and shape of the glove are decided by the size and shape of the hand and wrist and forearm. Each part of the glove is made as nearly as possible to the size and shape of the part of the hand or wrist or forearm over which it lies. The lengths of the straps are also decided by the size of the hand and wrist and forearm. The size and shape of the glove vary slightly with different hands, slightly larger gloves being required for large hands than for smaller hands. Similarly, the lengths of the straps vary slightly with different hands, slightly longer straps being required for large hands than for smaller hands.

The sizes and shapes of the various parts of the caestus are therefore closely related to the size and shape of the hand and wrist and forearm. The ring can be made of a certain size and shape, but of no other size and shape; the glove of a certain size and shape, but of no other size and shape; the straps of certain lengths, but of no other lengths. The only variations that can occur in the sizes and shapes of the parts of the caestus are caused by variations in the sizes and shapes of different hands and wrists and forearms.

The fastenings which hold the hand and the glove of the caestus together are formed partly by the hand and partly

by the glove; and the parts of the fastenings formed by the hand are complementary to the parts formed by the glove. The fork of the thumb forms a catch to help to prevent the glove being pulled up the arm; and the fork of the thumb of the glove helps to prevent the glove being pulled up the arm. The three forks between the fingers also form catches to help to prevent the glove being pulled up the arm; and the three forks between the fingers of the glove help to prevent the glove being pulled up the arm. The hand is larger than the wrist, and the parts of the hand near the wrist and the wrist together form a device which helps to prevent the glove being pulled off the hand; and the part of the glove round the hand is larger than the part round the wrist, and the two parts together act as a device which helps to prevent the glove being pulled off the hand. Each part of the glove is helped to remain fastened to the part of the skin over which it has been placed and to which it corresponds by the friction exerted between the part of the glove and the skin, or between the part of the padding next to the part of the glove and the skin; and relative movement of the part of the glove to the part of the skin over which it has been placed is partly prevented; and the frictional devices between the part of the glove and the skin, or the padding and the skin, are provided by the glove, or padding, and the skin together.

The glove forms a casing which conforms closely to the form of the hand and wrist and forearm. It is made to fit the hand and wrist and forearm approximately; and stretches when it is worn and comes still more closely to the form of the skin. The creases on the skin are fairly faithfully reproduced by the glove where it is in contact with the skin especially after the glove has been worn for some time. The glove forms an artificial surface over the skin, and closely resembles the skin in form and in the markings made by the creases on the skin; and the separate fingers and the grooves between the fingers nearly as far as the middle knuckles are reproduced by the glove.

The skin of the hand does not everywhere rest directly against the bones of the knuckles and joints. Padding

provided by the flesh and other components of the hand lies between the skin and the bones of the knuckles and joints. The padding between the skin at the back of the hand and outsides of the fingers and the bones of the knuckles and joints is less thick than between the skin at the palm and insides of the fingers and the bones of the knuckles and joints. The padding is especially thick at the palm between the skin and the bone of the thumb. The side of the hand near the little finger is thickly padded. When the hand forms a fist the ends of the fingers lie against the soft padding at the palm and the ball of the thumb, and when a blow is given by the middle knuckles the fingers are driven against the soft padding which helps to soften the blow to the joints and finger ends, and when a blow is given by the thumb the blow is softened for the thumb and fingers lying under the thumb. The glove of the caestus does not everywhere rest directly on the skin, but is padded in many places, and the thickness of the padding varies at different places. Thick padding is provided under the ring, and between the ring and the fork of the hand, and round the wrist and forearm. Many features of the hand and wrist and forearm are therefore reproduced artificially but crudely and imperfectly by the glove and its padding.

In addition to the fastenings joining the hand and glove fastenings are formed by the glove and the ring and straps to hold together the glove and the ring and straps. A bed or groove is formed on the surface of the glove in which the ring can lie, the bed or groove being formed by the pressure exerted by the inner surface of the ring on the glove. Grooves are also formed on the surface of the glove for the straps wound round the glove in which the straps can lie. The surface of the glove rises slightly along the sides of the straps and prevents the straps slipping sideways. The grooves formed on the surface of the glove for the ring and the straps are of the same lengths as the inner surface of the ring and the parts of the straps in contact with the glove. The inner surfaces of the ring and the straps form opposite types of fastenings to those formed on the surface of the glove, and

fit exactly into the grooves. The ring forms a clasp which helps to hold itself to the glove, and the straps form clasps which are shaped like the parts of the glove with which they are in contact, and the clasps help to hold the straps to the glove.

The forms of the inner surfaces of the ring and of the straps are partly impressed on the hand and wrist and forearm, because the pressure of the ring and of the straps is felt by the flesh through the glove. Similar grooves to those formed on the surface of the glove are formed also on the surface of the hand and wrist and forearm; but the human grooves are not as sharply defined as those on the surface of the glove. The ring and the straps press into the grooves on the outer surface of the glove, and the opposite impressions on the inside surface of the glove press into the grooves on the hand and wrist and forearm, and a close fit is then obtained of the ring and straps and glove and hand and wrist and forearm.

The form of the surface of the hand and wrist and forearm is almost exactly opposite to the form of the inner surface of the glove. If the hand and wrist and forearm could be removed from the glove and ring and straps without altering the forms of the hand and wrist and forearm and the forms of the glove and ring and straps, it could be seen that the shape of the hand and wrist and forearm was complementary to the shape of the inner surface of the glove. If then the ring and straps could be removed without altering their forms from the glove without altering its form, it could be seen that the shape of the parts of the outer surface of the glove which had been in contact with the ring and straps was complementary to the shape of the inside surface of the ring and straps. If the hand and wrist and forearm, and the glove, and the ring and straps, could then be placed together they would fit almost exactly together; and a close union of hand and wrist and forearm and glove and ring and straps would be obtained.

The manner of fitting the caestus to the hand and wrist and forearm is fairly clear. The caestus cannot be fitted to

the hand complete, for the hand is larger than the wrist and cannot be inserted into the glove unless the straps round the wrist are loosened. The glove is therefore first placed on the hand. It is open, or split, at the palm and wrist so that the hand can be inserted. The fingers are then inserted into the ring and the ring is pulled over the glove to fit closely round the hand and nearly into the fork of the thumb; but it is not easy to know whether the bands of the ring are placed one at a time over the hand or are first formed into a ring and tied together and then placed over the hand. The fingers are then bent so that their ends press on the ring; and the straps are wound round the hand and wrist and forearm of the glove, and their tensions are carefully adjusted so that they are complementary to the tensions exerted by the finger ends on the ring.

The ring and the parts of the glove and padding and straps between the ring and the hand cover the main knuckles and main finger joints and part of the hand near the main knuckles, protect them, and relieve them of the work of directly delivering a blow; but indirectly a blow given by the ring and parts of the caestus lying between the ring and hand is given by the human parts over which the ring lies, for the human parts are behind the ring and parts of the caestus lying between the ring and hand, and drive the artificial parts against the opponent. The main knuckles and main joints and part of the hand near the main knuckles are therefore partly replaced by the artificial parts which form artificial main knuckles and main joints and part of the hand near the main knuckles for the purpose of delivering a blow.

The ring and the parts of the caestus between the ring and hand do not relieve the thumb of the need for coming into contact with the opponent, for the thumb lies outside the ring. The blow, when the thumb hits the opponent, is directly given by the thumb, but indirectly also by the ring and parts of the caestus between the ring and hand, for the artificial parts are behind the thumb and help to drive it against the opponent.

When a blow is given by the back or side of the hand, the ring and parts of the caestus between the ring and hand protect the back or side of the hand and relieve it of the need for coming into contact with the opponent; and the blow is directly given by the artificial parts and indirectly by the human parts. When, however, the thumb hits the opponent, the thumb saves the ring and parts of the caestus between the ring and hand from coming into contact with the opponent, and the blow is directly given by human parts and indirectly by artificial parts.

The four main knuckles of the bare fist are approximately in a line which is at right angles to the arm. The main knuckles when the hand holds a caestus are approximately in a straight line across the hand and at right angles to the arm. The planes of the flat surfaces of the bands of the ring are also parallel to the line of the knuckles and at right angles to the arm. If the part of the ring lying over the back of the hand was separated from the rest of the ring and was turned through a right angle so that the parts of the bands of the ring pointed in the directions of the fingers, the parts of the bands would lie along the finger joints and along the continuations of the joints within the hand. If the ring was composed of four bands, each part of a band would then lie along a finger joint and its continuation within the hand, one part of a band to each finger joint and its continuation. The ring is usually composed of three, four, or five bands. The bands surround the four main knuckles and joints and partly replace them. They do not partly replace the thumb knuckles or joints, for the thumb is outside the ring; but they help to deliver a blow given by the thumb as the main part of the fist helps to deliver a blow given by the thumb. If the ring is composed of three bands, the three bands with their linings, or parts of the caestus lying between the bands and the hand, partly replace the four main knuckles and joints, and each band with its linings partly replaces more than one knuckle and joint. If the ring is composed of four bands, each band with its linings partly replaces one main knuckle and joint. If the ring is composed of five bands, the five bands with

their linings partly replace the four main knuckles and joints.

Most of the types of blows that can be given by the bare fist can also be given by the contrivance formed by the caestus and hand; for blows can be given by the middle knuckles of the contrivance, or by the middle joints, or by the thumb, or by the artificial main knuckles and joints and part of the hand near the main knuckles, or by the artificial side of the hand. Blows cannot be given by the top finger joints or finger nails of the bare fist, for they lie in the fist; blows cannot easily be given by the top joints or finger nails of the contrivance, but the top finger joints and the finger nails of the contrivance can come into contact with the opponent. The contrivance, however, can best be used to deliver types of blows which correspond to those given by the main knuckles or main joints or back or side or flat of the fist. If blows are given by the thumb or middle knuckles of the contrivance damage to the hand is more likely than when blows are given by the thumb or middle knuckles of the bare fist, for the weight of the caestus as well as the weight of the hand is behind the blow when the contrivance is used.

The part of the contrivance formed by the hand and the part of the caestus round the hand is held to the arm partly by human fastenings and partly by artificial fastenings. The hand itself is held to the arm partly by the skin, and partly by fastenings formed within the hand and extending to the arm. The finger ends pressing on the top of the ring are connected to the arm by fastenings formed by the fingers as far as the web of the hand and afterwards by continuations of those fastenings formed within the hand and wrist and forearm. The ring is held to the arm partly by the finger ends which press on top of the ring; and the fastenings holding it to the arm are therefore partly formed by the human fastenings which connect the finger ends to the arm The ring is also partly held to the arm by artificial fastenings formed by the straps or thongs connecting it to the parts of the glove round the wrist and forearm. The human fastenings

connecting the ends of the fingers to the arm and the artificial fastenings connecting the ring to the parts of the glove round the wrist and forearm are complementary in their actions; for if the human fastenings are tightened, that is, if the finger ends press more firmly on the top of the ring, the tensions of the artificial fastenings, or the straps, are decreased; and if the human fastenings are slackened, the tensions of the artificial fastenings are increased. The tensions of the straps must be so adjusted that undue strain is not placed at any time on the human fastenings; and the tensions must also be so adjusted that the ring is not held at any time too tightly against the fork of the thumb.

The ring is also partly held to the arm by the skin and glove. If the ring begins to move off the hand, the glove tightens and helps to prevent further movement off the hand. The skin and glove are in close contact and cannot easily move independently and therefore if the ring begins to move off the hand, the skin also tightens and helps to prevent further movement off the hand. If no glove were used, severe strain would be placed on the skin as it tightened; but part of the strain is taken by the glove and the glove therefore partly relieves the skin of the work of tightening to prevent the ring slipping off the hand. One of the reasons for the provision of the glove is the need for relieving the strain on the skin when the ring begins to move off the hand.

The artificial fastenings connecting the caestus to the arm besides helping to hold the caestus to the arm help to hold the hand to the arm. If the ring begins to move off the hand towards the middle knuckles, it begins to pull the glove off the hand and the glove begins to pull the skin off the hand. Any considerable movement of the ring is prevented partly by the tightening of the glove and of the straps, and the glove and straps therefore help to prevent the hand being pulled away from the arm and partly relieve the human fastenings connecting the hand to the arm of this work.

Much movement of the ring towards the wrist is partly prevented by the thick padding of the glove just below the main knuckles. The fork of the thumb of the glove especially

is thickly padded to prevent movement of the ring against the fork and hurt to the fork. Movement is also partly prevented by friction between the ring and glove which causes the parts of the glove between the ring and middle knuckles to tighten if the ring begins to move up the hand. As the glove tightens the three catches formed by the forks of the glove come against the three catches formed by the forks of the fingers and further movement is prevented. The skin between the top of the ring and the middle knuckles also tightens with the glove and helps to prevent the ring moving up the hand. The parts of the glove and of the skin between the top of the ring and the middle knuckles tighten together and act as a single device to help to prevent movement of the ring up the hand. If no glove were used, the skin would be subjected to much strain and might be injured in trying to prevent movement of the ring up the hand; but the glove relieves the strain on the skin, and partly replaces the skin in the work of preventing movement of the ring up the hand.

Movement of the ring towards the wrist may also be partly prevented by the plaiting of the straps or thongs between the fingers. Some illustrations of the later Greek caestus seem to show that a strap passed over the top of the ring and between the forefinger and middle finger and another one over the top of the ring and between the third and little fingers. If the straps are so plaited, as the ring begins to move up the hand the straps passed between the fingers come against the wedges of the fingers and help to prevent further movement of the ring. Movement of the ring up the hand may also be partly prevented by the ring coming against the straps or thongs wound round the fork of the thumb and part of the hand between the ring and wrist.

The contrivance bears some resemblances to the human fist and wrist and forearm. The top joints and knuckles and middle joints and knuckles of the contrivance closely resemble those of the fist, but their positions are modified, and they are placed farther from the wrist. The finger ends and the top joints of the fingers can be more clearly seen in

the contrivance than in the bare fist in which they are nearly hidden. The finger nails which are invisible in the fist are clearly visible in the contrivance. The top of the thumb of the contrivance is identical with the top of the thumb of the fist; but the lower part of the thumb of the contrivance near the hand is different, the outer surface being formed by the glove and padding and straps. The position of the thumb of the contrivance is slightly modified compared with its position on the fist, the thumb being pushed slightly outwards. The main knuckles and finger joints and part of the hand immediately below the main knuckles are represented in the contrivance by the ring and parts of the caestus between the ring and hand, and the artificial parts differ considerably in sizes and shapes and weights and materials and structures from their human counterparts. The part of the contrivance between the ring and the end of the glove at the forearm resembles corresponding parts of the fist and wrist and forearm; but its surface is formed by the artificial skin of the glove and not by the human skin. The fastenings which join the bare fist to the arm, except for the parts formed by the skin, are all within the hand; but the artificial parts of the fastenings joining the fist of the contrivance to the arm, except for the parts formed by the glove, are outside the glove and are visible.

The form of the hand holding the caestus is very similar to the form of the hand which holds the earlier type of caestus, and can similarly be obtained by unclenching the fist until the main joints and the palm form a flattish surface. The main joints of the fingers when the hand holds the caestus are approximately at right angles to the positions they occupy when the hand forms a fist. The middle joints are approximately at right angles to the flattish surface formed by the main joints and palm, and are approximately at right angles to the positions they occupy when the hand forms a fist. The main knuckles of the hand which in the bare fist are prominently formed and conspicuous are not prominently formed and lie almost in the flattish surface formed by the back of the hand and the main joints, and are hidden by the

caestus. The middle knuckles are prominently formed and are visible. A strong flattish surface is formed by the palm and main joints; but the ring is rigidly made and is not deformable and the form of its interior although determined by the form of the flattish surface made by the hand is not kept by the hand. The ring keeps its own form, and relieves the hand of the need for directly giving it its form and keeping it in form. The ring indeed helps to keep the form of the hand. The form of the glove and padding between the ring and hand, however, is partly given and kept directly by the hand, and the hand must still form a strong, flattish surface for this purpose. The form of the outer surface of the part of the glove which lies against the interior of the ring is given and kept directly by the ring, but indirectly by the hand which presses the padding and glove against the inside of the ring. The ring therefore partly replaces the hand in the work of forming a strong, flattish surface for the caestus.

The contrivance formed by the hand and wrist and forearm and ring and glove and straps consists of two main parts. A human part is formed by the hand and wrist and forearm and an artificial or mechanical part by the ring and glove and straps; and the human and artificial parts together form a fairly rigid contrivance. The contrivance is not quite rigid, for the relative positions of its component parts vary slightly during a wielding movement and especially during the delivery of a blow; but return approximately to their original positions relatively to each other after the wielding movement or after the delivery of the blow. The bare fist similarly is a fairly rigid contrivance, but the relative positions of its component parts vary slightly during a wielding movement and especially during the delivery of a blow; but return approximately to their original positions relatively to each other after the wielding movement or after the delivery of the blow.

The human parts of the contrivance are composed of living organic materials. The mechanical parts are composed of lifeless organic materials; but may be partly composed of inorganic materials if metal clasps are used to hold together

the bands of the ring. The materials and structure of the materials of the glove are very similar to the materials and structure of the materials of the skin. The materials and structure of the materials of the padding, which may be composed of wool or hair or some other organic material, differ considerably from the materials and structure of the materials of the padding of the skin which is formed by the flesh under the skin. If the straps or thongs are formed of leather their materials and structure of their materials closely resemble the materials and structure of the materials of the skin. The materials and structure of the ring resemble the materials and structure of the materials of the skin of the main knuckles and joints and part of the hand near the main knuckles, but do not resemble the materials and structure of the bones of the knuckles or joints; but the properties which give the knuckles and joints their hardness and sharpness are partly obtained for the ring by making it as hard and sharp as possible.

The heat of the hand is preserved by the glove whose heat conducting properties are very similar to those of the skin. The pores of the glove resemble those of the skin, but do not easily allow ventilation for the hand, for many parts of the glove are not directly in contact with the skin because of the padding; and the pores of the glove are partly useless because of being deformed and partly destroyed during manufacture of the glove. Ventilation is mainly effected by air and moisture escaping and air being drawn in between the ends of the fingers of the glove and fingers and through the open part of the palm of the glove.

The parts of the caestus are not all placed in the same relative positions to each other as corresponding parts of the fist. The ring and straps are not placed in the same positions relatively to the glove as their corresponding human parts are placed relatively to the skin. The main knuckles and joints and parts of the hand to which the ring corresponds are inside the skin; but the ring is outside the glove. The fastenings which connect the finger ends to the arm are inside the skin; but the straps or thongs are outside the glove. The

padding however which corresponds to the flesh and other soft parts of the hand is inside the glove as the human flesh is inside the skin.

The later Greek caestus does not form a complete weapon by itself. It cannot be formed except with the hand, and the hand must give it its shape, and keep it in shape during the wielding movements and during the delivery of a blow. It possesses no life of its own, and its parts cannot act against the opponent unless moved by the corresponding parts of the hand. Each part of the caestus is complementary to some part of the hand formed to hold the caestus; and the hand and caestus together form the complete weapon which is immediately wielded by the forearm.

Certain advantages are gained by the use of the later Greek caestus. A harder and heavier and sharper blow can be given than can be given by the earlier type of caestus or by the bare fist. But the advantages are accompanied by disadvantages. The later caestus is a much more elaborate contrivance than the earlier one, and requires much more time to make. Its materials are more difficult to obtain. More time is needed to fit it to the hand. It cannot be so quickly or easily wielded, for it is heavier and more cumbersome. The movements of the body and feet are slowed down, and the opponent can more easily see the preparations for a coming blow and avoid the blow. Greater strain is placed upon the wrist, for the ring is heavier than the ring of the caestus formed from a thong. The wrist is more firmly supported but cannot be fully supported because of the danger of constriction, and the wrist of the contrivance consisting of the human wrist and the parts of the glove and straps round the wrist cannot easily be so firmly set as when a soft thong forms the caestus or when the bare fist is used.

When a spherical stone is being wielded the fist is partly replaced by the stone. The wrist is not supported by artificial appliances, and all the fastenings joining the fist of the contrivance to the wrist and forearm are within the hand and wrist and forearm, and are human. Much strain is placed on the wrist, and therefore the fitting of a stone is not a very

satisfactory method of partly replacing the fist. When the early type of caestus is used, to help to relieve the strain on the wrist and forearm, the wrist and forearm are supported by parts of the thong. In order therefore to replace parts of the fist by means of a thong it becomes necessary also partly to replace parts of the wrist and forearm which wield the fist of the contrivance. When the later caestus is used more strain is placed on the wrist because the ring is heavier than the parts of the thong wound round the hand, and it becomes necessary to replace more of the parts of the wrist and forearm. The more fully the fist is replaced therefore the more necessary it becomes to replace more of the parts of the body which wield the fist.

CHAPTER 6

FURTHER OBSERVATIONS ON THE GREEK CAESTUS

THE ancient Greeks when producing the caestus or trying to improve it were probably unconscious that they were trying to replace parts of the fist or to replace parts more effectively; but it is clear that the earlier and later types of caestus were produced through attempts to replace parts of the fist by mechanical contrivances. A process of trial and error showed the materials that can be used, and the sizes and shapes and weights the different types can be made, and the ways in which the different types can be used.

Each part of a caestus resembles some part of the fist or wrist and forearm wielding the fist.

Most of the parts of the later caestus reproduce parts of the fist or wrist and forearm wielding the fist more clearly and less crudely than corresponding parts of the earlier caestus reproduce them. The main knuckles and joints and the part of the hand near the main knuckles are not very clearly reproduced by the main part of the earlier caestus, but it necessarily bears some resemblances to these parts because it surrounds them and takes their shapes. No attempt is made to reproduce the skin separately or the padding separately or the hard parts of the knuckles and joints separately or the fingers separately. An attempt is made in the later caestus to reproduce the skin and the padding and the hard parts of the knuckles and joints and the fingers separately. The skin of the main knuckles and joints and the part of the hand near the main knuckles is reproduced by means of the part of the glove between the ring and the hand, and the padding formed by the flesh is reproduced crudely by means of the padding of the glove. The hard parts of the knuckles and joints are reproduced

although very crudely and imperfectly by means of the ring, and the ring when made of several bands represents an attempt to reproduce the fingers separately. The human fastenings connecting the finger ends to the arm are crudely reproduced in the earlier caestus by means of the parts of the thong round the wrist and forearm, and in the late caestus less crudely but still very clumsily and imperfectly by means of the straps or thongs connecting the ring to the parts of the glove round the wrist and forearm. Neither the earlier nor the later caestus shows any attempt to reproduce the middle or top joints and knuckles of the fist or the top joints and knuckles of the thumb; but in the later caestus the lower part of the thumb is partly reproduced by the parts of the glove and straps round the lower part of the thumb. No attempt is made in the earlier or later caestus to reproduce the rigid parts of the forearm which help to wield the fist, for neither caestus possesses a handle of any sort, as a club possesses a handle, but is wielded immediately by the forearm. The parts of the later caestus, as might be expected, since it is a more developed and later form of the caestus, reproduce human parts less crudely and more faithfully than parts of the earlier caestus reproduce them; but the problems of replacing the fist are only imperfectly solved by means of the later caestus and therefore no very close correspondence of parts of the later caestus to human parts can be seen.

The parts or devices of a caestus occupy places close to the human parts to which they correspond.

The main part of the earlier caestus corresponds to the main knuckles and joints and part of the hand near the main knuckles, and surrounds these parts. The ring of the later caestus and parts of the caestus between the ring and the hand also correspond to the same human parts, and similarly surround them. The parts of the thong connecting the earlier caestus to the wrist and forearm or the straps connecting the ring to the parts of the glove round the wrist and forearm correspond to the human fastenings which hold the fist to the arm, formed by the fingers and their connections

within the hand and wrist and forearm, and follow somewhat the directions of the human fastenings and approximately lie along them. The glove of the later caestus, which corresponds to the skin, lies over the surface of the skin; and each part of the glove corresponds to the part of the skin over which it lies. Each finger or the thumb of the glove corresponds to part of the skin of a finger or thumb and lies over the part of the skin of the finger or the thumb to which it corresponds. Each crease in the glove corresponds to the crease in the skin immediately under the crease of the glove. Since the caestus does not very successfully replace parts of the fist and wrist and forearm wielding the fist, its parts do not always occupy places quite close to their corresponding human parts. The fastenings joining the main part of the early caestus or the ring of the later caestus to the arm, for example, do not follow the human fastenings very closely, but some correspondence of the positions of the artificial fastenings and human fastenings can be seen.

Each part of a caestus is related in size and shape to the size and shape of its human counterpart.

The glove of the later caestus is made as nearly as possible to the size and shape of the skin of the hand and wrist and forearm over which it lies. It cannot be made of the same size and shape because it must lie over the skin, and room must be allowed for the padding. It must not be made larger than is necessary to allow room for the hand and padding or it will not fit properly. The lengths of the parts of the thong wound round the wrist and forearm or the lengths of the straps wound round the wrist and forearm of the glove are determined by the size and shape of the wrist and forearm of the wielder; and the parts of the thong or the straps must be of lengths which allow the parts of the thong or the straps to work in co-operation with the human fastenings holding the ends of the fingers to the arm. Similarly, other parts of a caestus can be seen to be directly or indirectly related in sizes and shapes to the sizes and shapes of their human counterparts.

Each part of a caestus partly replaces its corresponding human part or parts.

The ring of the early caestus partly replaces the main knuckles and main joints and part of the hand near the main knuckles, for the human parts are not required to come into contact with the opponent and hit the opponent directly, and the work of hitting the opponent is directly carried out by the ring. The ring does not fully replace its corresponding human parts, because the human parts are still needed to drive the ring against the opponent, and to form complementary parts of the ring. Similarly, the ring of the later caestus and the parts of the caestus between the ring and the hand partly replace the main knuckles and main finger joints and part of the hand near the main knuckles. The fastenings holding the ring of the earlier caestus or the ring of the later caestus to the arm partly replace the fastenings formed by the finger ends and their connections to the arm in the work of holding the caestus to the arm, for they partly release the finger ends from the need for holding the caestus to the arm. They do not fully replace the human fastenings, for the finger ends are still needed to help to hold the caestus in place. The glove partly replaces the skin in the work of helping to hold the ring to the arm, for it tightens if the ring begins to move off the hand; but it does not fully release the skin from the need for tightening, and therefore does not fully replace the skin in its work of helping to prevent the ring slipping off the hand. The padding in the fork of the thumb of the glove partly replaces the flesh of the fork of the thumb in preventing the ring moving up the hand towards the wrist; but the flesh of the fork of the thumb must still be placed behind the padding, and the padding therefore only partly replaces the flesh of the fork of the thumb in the work of preventing the ring moving up the hand.

The work of each part of a caestus is complementary to the work of its human counterpart.

A blow given by the main knuckles of the contrivance formed by the early caestus and the hand is given by the part of the caestus lying over the main knuckles and the main

knuckles working together. The part of the caestus lying over the main knuckles comes into contact with the opponent and directly delivers the blow; but the main knuckles drive the part of the caestus lying over them against the opponent and indirectly deliver the blow, and the work of the part of the caestus is complementary to the work of the main knuckles. Similarly, when a blow is given by the main knuckles of the contrivance formed by the later caestus and the hand, the work of the part of the ring at the back of the hand and its linings is complementary to the work of the main knuckles.

The parts of the thong of the early caestus which are wound round the wrist and forearm act as complementary parts of the fastenings formed by the skin and of the fastenings formed by the fingers and their connections within the hand and wrist and forearm. The parts of the thong must help to hold the main part of the caestus to the arm in co-operation with the fastenings which connect the finger ends to the arm. They must help to hold it to the hand in co-operation with the skin. When the caestus begins to move off the hand, the skin tightens and the thongs tighten, and the skin and thongs work together to help to prevent the caestus moving off the hand. They must help to hold the hand to the arm in co-operation with the fastenings which connect the finger ends to the arm. When the caestus begins to move off the hand, it presses against the finger ends and tends to pull the hand away from the arm; but the thongs tighten and the finger ends press more firmly on the caestus, and the thongs and fastenings holding the finger ends to the arm help to prevent the hand being pulled away from the arm. They must help to hold the hand to the arm in co-operation with the skin. When the caestus begins to move off the hand, it drags the skin with it; but the skin tightens and the thongs tighten also, and the skin and thongs together help to hold the hand to the arm.

The work of the padding of a caestus is complementary to the work of the padding formed by the flesh. The force of a blow is softened for the hand partly by the padding and

partly by the flesh. When a blow is given by any part of the early caestus, the padding of the part of the caestus which delivers the blow and the flesh under the part of the caestus which delivers the blow act as a single device to soften the blow for the hand. Similarly, when a blow is given by the ring of the later caestus the padding of the part of the glove under the part of the ring which delivers the blow and the flesh of the hand under the padding act together as a single device to soften the blow for the hand. The padding of the glove at the fork of the thumb and the padding formed by the flesh of the fork of the thumb act together as a single device to keep the ring from moving too far down into the flesh and to prevent the ring hurting the thumb. The padding of the glove under the ring and the flesh of the hand under the ring act together as a single device to allow the ring to form a bed or groove in which to lie and to prevent the ring hurting the hand. The padding of the glove and the flesh under the glove at the wrist and forearm together allow the straps to form grooves in which to lie and to prevent hurt to the bones and other parts of the wrist and forearm. The inner surface of the ring of the early caestus forms a kind of artificial skin and acts with the parts of the skin with which it is in contact to help to prevent the caestus moving up or down the hand. If the caestus begins to move up or down the hand, friction comes into play between the skin and the inner surface of the caestus to help to prevent movement of the caestus up or down the hand. Each part of the glove of the later caestus and the part of the skin over which it lies work together. The part of the glove between the ring and the wrist and the skin over which it lies tighten together to help to hold the ring to the hand and the hand to the arm. The part of the glove between the ring and the three forks of the fingers of the glove and the skin over which it lies tighten together to help to prevent the ring moving up the hand towards the wrist. The three forks of the glove and the skin of the three forks of the fingers act together to help to prevent the ring moving up the hand towards the wrist. The fork of the thumb of the glove and

the skin of the fork of the thumb together help to keep the ring from moving too far down into the fork of the thumb.

The fitting of a caestus causes modifications in the form of the fist.

The form of the hand is much the same when holding either the earlier or later Greek caestus. The main parts of the caestus are placed round the main part of the hand; and the finger ends do not rest on the palm as they do when the hand forms a fist, but are displaced by the main parts of the caestus which occupy the hollow of the hand between the ends of the fingers and the palm, and the finger ends rest on top of the caestus. The main joints form a flattish surface with the palm, instead of being approximately at right angles to the palm as in the fist; and are in positions approximately at right angles compared with their positions in the fist. The main joints are still parallel to each other; and the middle joints to each other; and the top joints to each other. The main knuckles are not prominently formed and lie almost in the flat surface formed by the back of the hand and the main joints. The middle knuckles are not quite as sharply formed as in the fist but are prominently formed. The top knuckles are not quite as prominently formed as in the fist, but can be more clearly seen. The finger nails which are not visible in the fist can be clearly seen when either the earlier or later caestus is held. The position of the thumb is only slightly modified when the thumb is not covered by the thong of the earlier caestus. Its position is modified when the later caestus is held because the lower part near the hand is covered by padding and the glove and straps. The form of the skin and the positions of the fastenings within the hand and wrist and forearm are slightly modified because of the pressure of the thongs or glove and straps.

Advantages for certain purposes are gained by partly replacing the fist by a caestus.

The use of a caestus allows a heavier and harder blow to be delivered than can be delivered by the bare fist. A blow given by the ring of an early caestus and its human counterparts is heavier and harder than one given by the human

parts alone; and a blow given by the ring of the later caestus and its linings and their human counterparts is heavier and harder and sharper than one given by the human parts alone, or by the ring of the earlier caestus and its human counterparts. The increased powers given by use of a caestus are, however, accompanied by disadvantages. The caestus and hand together are heavier and more cumbersome and difficult to wield than the bare fist, and the movements of the wielder are slower than those of the wielder of a fist. The advantages may outweigh the disadvantages for certain purposes. If it is required to give a heavy blow and there is time to make the caestus and fit it to the hand, the hand and caestus may be more effective than the bare fist; but if a blow must be given quickly, the bare fist may be more effective. It cannot be shown that an advantage can be gained that is not accompanied by a disadvantage.

A complete weapon is formed by the hand and the caestus.

A caestus by itself does not form a weapon. It cannot be formed except with the hand. Without the hand it must remain a thong or a collection of articles consisting of a glove and a ring and straps. The hand must give it its shape, and keep it in shape while it is being wielded and while a blow is being delivered. By itself a caestus is incapable of any actions, and until fitted to the hand and moved by the hand must remain inanimate and formless and shapeless. A caestus is moved by the hand; and each part of it is moved against the opponent by its human counterpart, and each part is made to carry out movements very similar to those carried out by its human counterpart. The size and form and shape and materials and structure of the materials of any part of a caestus cannot be understood if studied without reference to the size and form and shape and materials and structure of the materials of its human counterpart. The relationships between the earlier and later caestus cannot be known unless each is studied with reference to the hand, for the complementary parts of each are formed by the hand. Each part of the complete weapon formed by the hand and a caestus

is correlated to all the other parts of the weapon; for all parts act in concert, and any alteration in the form of a human or mechanical part of a weapon demands and compels alterations in the forms and shapes and actions of all the other parts. The weapon is also correlated to the machinery of the body which wields the weapon, and all parts of the weapon and of the wielding machinery act together and any alteration in the form of any part of the weapon affects all the movements of the body.

CHAPTER 7

ROMAN TYPES OF THE CAESTUS

A TYPE of caestus made by the Romans has a metal bar fastened to the back of the hand, *Figure 2.* The bar lies over the main joints and knuckles of the fingers and part of the hand near the main knuckles. It is fairly flat on its outer surface; but is curved over the little finger and over the forefinger and thumb. It is fastened to a glove which covers the wrist and part of the forearm. The bar appears to be made of three pieces crossing the hand at right angles to the finger joints and apparently has two connecting pieces lying in the directions of the finger joints. The thumb is covered; but the ends of the fingers are uncovered and free. The bar is connected to the wrist and forearm by means of the glove and straps or thongs.*

FIG 2.
ROMAN BOXING GLOVE
British Museum Guide Book

The size and shape of the metal bar are determined by the size and shape of the hand. It is an advantage to have as large a bar as possible; but the ends of the bar must not project much over the sides of the little finger and the forefinger and thumb, because if they project to any appreciable extent and the opponent is hit by an end, the leverage will be likely to tear the bar from the glove and the fastenings. The greatest length for the bar is obtained by curving one end well over the forefinger and thumb and the other end over the little finger. Curving an end partly prevents leverage taking effect and enables the end to be supported when a blow is given by the end. The front edge of the bar must reach to the middle knuckles; but must not project beyond. If it does not reach to the middle knuckles, the blow will be

* British Museum Handbook, *A Guide to Greek and Roman Life.*

given by the middle knuckles instead of by the front edge of the bar, and the momentum of the bar will tend to carry the bar on to the opponent and pull the glove forward or tear the bar from its fastenings. If the bar extends beyond the middle knuckles, the hand will continue to travel on after the front edge of the bar has hit the opponent, and the wrist may be sprained or the bar may be torn from its fastenings. If the bar just reaches to the knuckles, the bar and the knuckles are more likely to be stopped together, and less strain will be placed on the fastenings. The bar must not extend down the back of the hand much beyond the main knuckles; because if a blow is given by the part of the bar nearest the wrist, the momentum of the front of the bar will be unchecked and the fingers may be bent backwards and be strained. The thickness of the bar is determined partly by the need for preventing too much leverage to force the hand backwards if the opponent is hit by a front edge. The bar is placed on padding over the main joints and the padding raises the bar slightly, and the need for padding reduces the height to which the bar can be made above the hand.

The bar is approximately half of a complete ring that might be placed round the hand. The ends of the bar are curved as if to enter the hand; but the half that would lie within the hand is missing. The placing of a metal bar on the outside of the hand partly solves the problem of replacing the fist by means of metal. As the half of the bar that would lie in the hand is missing, danger of sandwiching is prevented as long as the bar and not the part of the hand opposite the bar is used.

The types of blows that can best be given by the contrivance are those given by the back of the bar and by its front edge. These types correspond approximately to those that can be given by the main knuckles and finger joints and by the middle knuckles of the bare fist.

The bar lies over the main knuckles and finger joints, protects them, and releases them from the need for coming into contact with the opponent and directly delivering the blow. It partly replaces the main knuckles and finger joints;

but does not fully replace them because they must drive the bar against the opponent. The bar also lies over the middle knuckles, partly protects them, and partly releases them from the need for directly delivering the blow. The bar therefore also partly replaces the middle knuckles.

The bar is heavy and the wrist must be strongly supported; and the glove at the wrist is well bound with straps so that the wrist of the contrivance can be firmly set especially at the moment of delivering the blow.

The contrivance bears some resemblances to a fist and wrist and part of a forearm. The middle knuckles and joints are similar to those of the fist, but their positions are modified. The end joints which in the fist are hidden are visible in the contrivance. The form of the thumb is modified, for it is covered by the glove. The wrist and part of the forearm bear some resemblances in form to the human wrist and forearm. The artificial fastenings connecting the fist of the contrivance to the arm are formed by the glove and straps or thongs, and the straps or thongs are outside the glove. The main knuckles and finger joints and part of the back of the hand of the contrivance are formed by the metal bar and its linings. The contrivance consists of two main parts. A human part is formed by the hand, and a mechanical part by the caestus. The caestus is composed partly of organic and partly of inorganic materials. The bar is made of inorganic materials, and in materials and structure of materials does not bear close resemblance to its human counterparts.

The form of the hand is similar to its form when holding the later Greek caestus. The main joints form a flattish surface with the palm, and the two top joints are bent to keep the flattish surface firm.

The fastenings joining the glove to the hand and wrist and forearm are formed in much the same way as when the later Greek caestus is held, and are partly human and partly artificial. The fastenings joining the bar and straps to the glove are formed in much the same way as when the later Greek caestus is held, and are artificial. The glove fits the hand, and the bar and straps fit the glove, and a single

contrivance is formed from the hand and glove and bar and straps.

Another type of Roman caestus completely encloses the hand and forearm and sometimes the upper arm as far as the shoulder. Pieces of lead or iron are sewn into the caestus; but the positions of the pieces and the ways in which they are sewn into the caestus are not known. The hand appears to be encased in a hard ball or cylinder, and requires to be supported by a padded sleeve strapped to the wrist and forearm and upper arm.

The fastenings which hold the hand and arm and the glove and sleeve together are formed partly by the hand and arm and partly by the caestus. The fastenings which hold the glove and sleeve and the straps together are formed partly by the glove and sleeve and partly by the straps. The glove and sleeve fit the hand and arm, and the straps fit the glove and sleeve, and a single contrivance is formed by the hand and arm and glove and sleeve and straps. The part of the contrivance as far as the elbow is fairly rigid, and the various parts cannot be separately manipulated or have independent movements; but the lower arm and fist of the contrivance can move relatively to the upper arm. Some small variations of positions of parts of the lower arm and fist of the contrivance relatively to each other take place during a wielding movement and during the delivery of a blow, but the parts return to the positions they occupied originally relatively to each other.

The fastenings which hold the fist of the contrivance to the arm are formed partly by the hand and arm and partly by the caestus. Although the ways in which the human fastenings are formed cannot be seen, probably they are formed in much the same ways as for the other types of contrivances which have been studied. The artificial fastenings are also formed in much the same ways; but are of much greater length and extend much farther up the arm. They extend much farther up the arm because the greater weight of the fist of the contrivance requires that more support shall

be given to the wrist and forearm and that some support shall be given even to the upper arm. They are formed partly by the sleeve and partly by the straps. The sleeve forms a kind of artificial skin, and acts in much the same way as the skin acts in helping to hold the fist to the arm. The sleeve partly releases the skin from the work of helping to hold the fist of the contrivance to the arm. The straps similarly partly relieve the human fastenings within the arm of the need for helping to hold the fist of the contrivance to the arm.

Some of the flexible parts of the forearm and upper arm which wield the fist of the contrivance are partly reproduced artificially by means of the sleeve and padding and straps; but none of the rigid parts of the forearm and upper arm which wield the fist are reproduced artificially by the caestus. The caestus has no handle like the handle of a club; and the handle which wields the caestus is formed by the bones of the forearm and upper arm and lies within the skin and sleeve, and does not extend beyond the hand as the handle of a club extends beyond the hand. The fist of the contrivance is immediately wielded by the forearm and upper arm; and the flexible parts of the forearm and upper arm, which are partly reproduced by the sleeve and straps, lie along the forearm and upper arm, and surround the rigid parts of the wielding handle formed by the bones of the forearm and upper arm within the skin.

The contrivance bears some resemblances to a fist and forearm and upper arm; but the separate knuckles, joints, nails, and the thumb, and other details of the fist, are not seen in the contrivance. The skin of the fist and arm is reproduced crudely by the sleeve. The artificial parts of the fastenings holding the artificial skin to the wrist and arm, and the artificial parts of the fastenings holding the fist of the contrivance to the arm, are not within the artificial skin as the human fastenings holding the skin to the hand and the fist to the arm are within the skin, but are outside the artificial skin and are visible. The padding and the metal parts are within the artificial skin and are invisible.

By means of the contrivance a very heavy blow can be

delivered, but the advantage of being able to deliver a very heavy blow is accompanied by disadvantages. The contrivance is cumbersome and heavy and cannot be quickly or easily moved. A firmly set wrist cannot easily be obtained. Constriction of the wrist and arm is difficult to avoid. Support must be given not only to the wrist and lower forearm but to the whole forearm and sometimes even to the upper arm.

Chapter 8

THE BRACCIALE

IN his treatise on the game of pallone, Dr. A. L. Fisher gives an illustration from a book of 1555 A.D., of two young Romans playing with the follis, which is a ball something like a modern football. The right forearm of each player has "a leather strap, or other material, bound round it like a caestus." In the illustration, the strap seems to be over a wrist gauntlet; and the contrivance somewhat resembles *the Greek caestus made from thongs wound* round a glove, but without the hard leather rings or bands. The ball is being struck with the wrist of the contrivance.

Strutt says the follis of the Romans was beaten backwards and forwards by the players with the fist. In the time of Comenius, 1592-1670, the balloon-ball which resembled the follis was hit by players who had a round hollow bracer of wood to cover the hand and lower part of the arm. This game seems to have resembled the modern Italian game of pallone, and the bracer the bracciale or wooden gauntlet used in the game. This game with its apparatus has been described by Dr. A. L. Fisher,[1] who has given numerous illustrations of the apparatus, some of which are shown in *Figures 3, 4*. Extracts from his description of the bracciale follow:—

" . . . The bracciale, in English bracelet or gauntlet, is a hollow wooden cylinder, nine inches long and eight inches in diameter, with which the ball is struck in the game of Pallone. This instrument is held in the right hand by introducing the hand into the smaller end, as into a lady's muff, and seizing firmly at the further extremity a round

[1] A. L. Fisher, M.D., *The Game of Pallone.*

piece of wood one inch and a half in diameter, which passes obliquely across from one side of the hollow cylinder to the other. This cylinder is composed of a heavy inner body or frame, and of an outer covering of pyramidal points stretching outward from the axis of the instrument, like the spokes

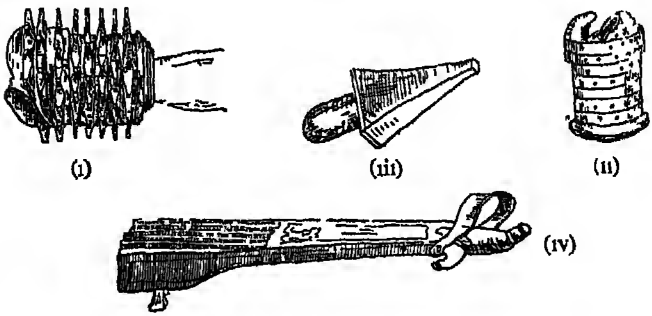


Fig. 3.

(i) Bracciale on hand
(ii) Inner body or frame of bracciale divested of its outer covering of points
(iii) One of the points
(iv) Scanno, or wooden club used formerly instead of the bracciale A. L. Fisher, M.D., *The Game of Pallone.*

from the nave of a wheel. The inner frame is always cut out of a solid piece of walnut-tree, and the points are made of pear-tree or other wood of close grain, which is not likely to be easily broken . . . the inner body or frame of the bracciale divested of its outer covering of points . . . is of two distinct diameters—the smaller one of five inches, which covers the wrist, and the wider one of six inches, which is carved out, so as to allow the hand to grasp the cross-handle. The points are all separate, and each made of a piece of wood of three inches long, one inch of which is turned perfectly round, and half an inch in diameter, and the remaining two inches are curved into a flat pyramidal point, terminating in an extremity of a quarter of an inch square . . . All over the outside of the inner frame holes are disposed in circles, which are drilled for the purpose of receiving the round ends of the points. When all these are inserted, the bracciale is

uniformly increased to eight inches in diameter; for though the inner body is of two different diameters, as the points for the wider part are made one inch shorter than those for the narrow one, this disparity is thus counteracted . .

"The object of these spikes appears to be, to enable the player, by giving a slanting direction to his stroke, to impart to the ball a rotatory motion, similar to what is produced when a cut is given to the ball by the racket in the game of tennis . . ."

The weapon or implement consists of two main parts, a human part being formed by the fist and wrist and forearm, and an artificial or mechanical part by the bracciale. To fit the bracciale to its human counterparts, the hand and forearm are inserted through the open end of the spiked cylinder, and the hand then grasps the bar at the forward end, the fingers being clenched round the bar. The bracciale is somewhat like a motor car or motor-bicycle piston, with the bar corresponding to the gudgeon pin, the hand and arm corresponding to the crank. The human part of the fist does not protrude from the wooden cylinder; and the fist of the implement is formed partly by the nearly clenched fist of the wielder and partly by the part of the bracciale which lies around his fist. The wrist similarly is formed by the wielder's wrist and the part of the bracciale around it. Similarly, the forearm is formed partly by the wielder's forearm and partly by the wood of the cylinder of the bracciale.

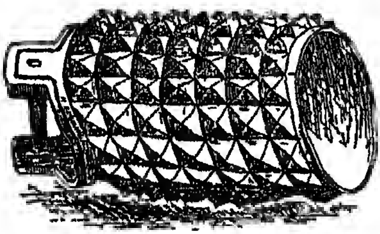


FIG. 4.
BRACCIALE MADE OF ONE PIECE OF WOOD
A. L. Fisher, M.D.

The skin of a glove provides the skin of the hand and arm of its wielder with an artificial or mechanical extension and corresponds to it. The wooden cylinder of the bracciale occupies much the same position as a glove; but does not lie so closely over the human skin. Also, it does not reproduce

the human skin with any fidelity. It is perhaps an artificial extension for the skin; but probably also provides an artificial extension for the rigid and hard parts of the arm as well. Clearly, since no parts of the bracciale are soft or flexible, the soft and flexible human parts are not given mechanical extensions by means of the bracciale. The bar fills the hollow or barrel of the hand.

The bracciale has 93 wooden spikes projecting at right angles to its surface. They are arranged in eight rings round the cylinder, but the number in the rings varies, those in the first two rings for example having fewer spikes than those in the other rings. Each ring of spikes has the appearance of the cogs on say the chain sprocket of the back wheel of a bicycle; and the bracciale itself might easily be mistaken for some kind of gearing with numbers of toothed wheels.

Each of the spikes is at right angles to the axis of the cylinder. Some of the joints of the fingers of the hand clenched within the bracciale appear to be parallel and others to be in a plane at right angles to the axis, approximately, the second joints being in a plane at right angles to the axis, and the first and third joints in planes parallel, approximately, to the axis. It seems the cogs or spikes are mechanical extensions of the devices formed by the finger joints and mechanical counterparts of them.

CHAPTER 9

THE MODERN BOXING GLOVE

THE modern boxing glove is a form of the ancient caestus. It is not a weapon by itself, but forms a weapon together with the hand. The weapon consists of two main parts. A human or natural part is formed by the hand, and an artificial or mechanical part is formed by the glove. The two parts are complementary. The hand forms most of the inner parts of the weapon, and the glove most of the outer parts. The glove is kept clenched by the hand; and the hand is helped to remain partly clenched by the glove. The surface of the hand and the internal surface of the glove correspond fairly closely in shapes The correspondence of any internal part of the glove to the surface of the hand over which it lies is momentarily increased when the external part opposite the internal part hits the opponent, for the internal part is then pressed hard against the hand, and the hand and glove at that place momentarily take each other's shape more faithfully. For example, if the part of the glove over the main knuckle of the forefinger hits the opponent, the interior of the glove opposite the main knuckle of the forefinger takes the shape of the knuckle very closely while the blow is being delivered, because the part of the glove over the knuckle is pressed hard against the knuckle. The hand and glove move together in all movements; and each part of the hand and its corresponding artificial part formed by a part of the glove move together in all movements; and the glove and hand cannot have independent movements. The hand and glove form a fairly rigid contrivance; but the parts of the contrivance may move slightly relatively to each other during the wielding movements.

The fastenings which hold the glove and hand together are formed partly by the hand and partly by the glove. The

glove surrounds the hand and fingers, and the thumb of the glove surrounds the thumb, and the glove can therefore remain easily on the hand The hand is larger than the wrist, and when the glove is tied at the wrist the part of the hand near the wrist and the wrist together form a device to prevent the glove being pulled off the hand The fork of the thumb provides a catch to prevent the glove moving up the hand; and the middle knuckles of the fingers press against the inside of the glove and help to prevent the glove moving up the hand Both the glove and the flesh of the hand are deformable, and pressure between the glove and hand helps to produce a fairly close fit of glove and hand.

The creases on the palm and insides of the fingers and thumb are reproduced on the surfaces of the palm and inside of the thumb of the glove, especially after the glove has been used for some time. The creases on the outsides of the hand and fingers are not reproduced on the outside of the glove because the parts of the glove lying over the outsides of the hand and fingers do not lie directly on the hand and fingers but over the padding between the hand and fingers and the glove. The creases on the outside of the thumb similarly are not reproduced on the glove because of the padding between the outside of the thumb and the glove. The grooves between the fingers may be faintly reproduced momentarily when a blow is given, for the glove may be pressed hard against the fingers and the form of the finger joints may be faintly reproduced on the skin of the glove. Similarly, the forms of the knuckles may be faintly reproduced momentarily on the outside surface of the glove when a blow is given. They may also be faintly reproduced if the hand is firmly clenched, and the glove is tightly stretched.

The glove, except at the palm and inside of the thumb, is padded, and the skin of the glove does not rest directly on the hand. The padding softens the force of the blow for the hand and prevents damage to the hand. The padding under the skin of the glove and the flesh under the skin act together to soften a blow and protect the hand from injury, for when a blow is delivered by any part of the glove the padding

beneath that part and the flesh underneath the padding are compressed and act together as a single device to soften the blow for the hand. Where there is little flesh over the part of the hand which delivers the blow the work of softening the blow for the hand is mainly carried out by the artificial padding; but may also be partly carried out by the padding formed by the flesh at the inside of the hand against which the fingers are pressed by the force of the blow.

The wrist is constructed to wield the fist, but not the fist and a glove; but the wrist is supported by the part of the glove round the wrist and by the tapes if they are tied round the glove. The wrist of the contrivance, which consists of the human wrist and the part of the glove round the wrist, can be fairly firmly set if the glove is tied fairly tightly at the wrist; but if the glove is tied too tightly the wrist will be constricted and unable to wield the contrivance properly.

The contrivance is held to the arm by fastenings which are partly human and partly artificial. The hand is held by human fastenings formed within the hand and wrist and by the skin. The glove is held to the arm partly by human fastenings and partly by fastenings formed by the glove. The fingers inside the glove are hooked round parts of the glove, and are held to the arm by fastenings formed by the fingers as far as the web of the hand and afterwards by connections within the hand and arm. The skin also helps to hold the glove to the arm; for if the glove begins to move off the hand, the skin tightens and helps to prevent further movement. The inside of the glove and the skin of the hand are not fastened so closely as the inside of the glove of the later Greek caestus and the skin, and the skin does not play such an important part as it does in holding the later Greek caestus to the arm. The skin of the glove plays an important part in holding the glove to the arm. When the hand is firmly set, just before delivery of a blow or during the delivery of a blow, the skin of the glove is very tight, and then exerts most tension to hold itself to the arm. The glove is held to the arm partly by the laces. The palm of the glove is split and the glove is laced when it is placed on the hand,

and sometimes the ends of the laces are wound round the parts of the glove round the wrist.

The contrivance has some resemblances to the human fist and wrist, but is larger and less irregular. The knuckles, finger joints, finger nails, grooves, creases, and other features of the fist, are not reproduced with any fidelity by the contrivance; but some of them are faintly reproduced when the opponent is hit. The contrivance has a separate thumb which is placed very similarly to the way the thumb is placed in the bare fist, over the parts of the glove which cover the forefinger and middle finger or at the side of the forefinger. The skin of the contrivance is smoother than the skin of the fist, and is darker in colour, usually being dark brown in colour or wine coloured. The only fastenings holding the glove to the arm which can be seen, except for those formed by the skin of the glove, are the laces on the palm of the glove and inside of the wrist of the glove, and the parts of the laces round the glove at the wrist if the laces are tied round the glove. Various seams can be seen on the palm and inside of the thumb and round the wrist of the glove.

The contrivance consists of two main parts. A human part is formed by the hand, and an artificial part by the glove. The core of the contrivance is formed mainly by human parts, and the outer parts mainly by artificial parts. The human parts are composed of living organic materials, but the artificial parts of lifeless organic materials. The artificial parts have no power of their own of carrying out offensive actions, but when fitted to the hand come into working relationships with the offensive machinery of the body and carry out offensive actions.

The hand when wielding a boxing glove is partly unclenched. The finger ends do not reach to the palm but are separated from it by the thickness of the padding which lies inside the finger ends when the hand of the glove is open, and by the lining of the palm of the glove, and by the tape which laces the palm of the glove. When the thumb is placed against the side of the forefinger, the lining of the inside of the thumb of the glove and the lining over the side of the

forefinger and some of the padding over the forefinger prevent the thumb lying directly against the side of the forefinger, and it is displaced slightly outwards compared with its corresponding position in the fist. The main knuckles are less prominently formed than when formed for the bare fist. *The main and middle joints are approximately at right angles* to each other. The finger tips are approximately in a straight line.

Many boxing gloves possess a bar grip formed by a band of leather or by a length of hard padding sewn across the palm of the glove. The bar is almost opposite the crease formed where the fingers meet the palm, and is approximately in the same position as a pencil or other thin rod held in the fist,* and is at right angles to the main and middle and top joints of the fingers and to the direction of the arm, and parallel to the lines of the main and middle and top knuckles and finger ends. The hand closes round the bar when the glove is clenched, and the bar partly fills the hollow of the hand. The bar is not heavy enough to weight the hand to any appreciable extent, and does *not* appreciably make the hand liable to damage through sandwiching The tape which laces the palm of the glove is tied round the wrist of the glove, and is clearly a modern variation of the parts of the thong or straps of the Greek caestus which were wound round the wrist and forearm, for it helps to hold the glove to the arm as the thong or straps helped to hold the caestus to the arm.

The size and shape of the glove are determined within close limits by the size and shape of the hand. The glove must not extend much beyond the ends of the fingers, because the hand must be nearly clenched, and the end of the glove must be contained within the hand. The thickness of the glove over the side of the forefinger and the thickness of the lining of the inside of the thumb of the glove must not be sufficient to force the thumb outwards to any considerable extent. To allow the hand to be nearly clenched the parts of the glove lining the palm and insides of the fingers must

* See chapters 12 and 23.

not be padded. The thickness of the padding over the main finger joints must be sufficient to deaden the force of the blow to the hand; but if more than sufficient for this purpose, the opponent will be pushed rather than hit.

The glove cannot be weighted above the main joints or main knuckles or middle knuckles without altering the form of the glove and its fastenings. If the glove were much weighted over the main joints or main knuckles or middle knuckles, the form of the glove would have to be considerably altered to provide more support for the wrist and forearm and perhaps support would also have to be provided for the upper arm, and the glove would revert to a form somewhat similar to that of the ancient Roman caestus which has a sleeve and straps extending sometimes to the shoulder; and the disadvantages attending the use of a caestus extending over the forearm and the upper arm would again be felt.

The hand is fully released from the need for coming into contact with the opponent and directly delivering the blow; and the opponent is directly hit by the glove which therefore partly releases the hand from the need for forming knuckles and joints for use against an opponent. But the glove does not fully replace the fist, and the hand must still form knuckles and joints within the glove, and indirectly deliver the blows directly given by the glove. The glove releases the skin from the need for coming into contact with the opponent; but does not fully replace the skin in the work of wielding the contrivance; and the skin still tightens to hold the glove if the glove begins to move off the hand, and it still helps to join the hand to the interior of the glove.

The types of blows that can be given by the contrivance are fewer in number than can be given by the bare fist, because the contrivance does not possess clearly defined finger and thumb knuckles and joints, and the many and various types of blows that can be given by the fist cannot be given by the contrivance. But most of the main types of blows that can be given by the fist can also be given in modified forms by the contrivance.

The skin of the glove releases the skin of the hand from

the work of coming into contact with the opponent; and the padding of the glove partly releases the padding formed by the flesh and other soft parts of the hand from the work of softening the blow for the hand. The boxing glove does not partly replace the hard parts of the hand; and the knuckles of the contrivance must still be formed by the knuckles within the glove. The knuckles of the contrivance are so protected by artificial padding that they are less effective in delivering hard and sharp blows, and as a result the contrivance has a tendency to push rather than hit the opponent.

Advantages are gained by the use of the modern boxing glove; but the advantages are accompanied by disadvantages. A heavier blow can be delivered by the glove than by the bare fist; but the blow from the glove and hand is not as hard and heavy as the blow from the bar of a Roman caestus or the ring of a Greek caestus. The skin of the hand and the knuckles and joints are well protected from damage; but the clearly defined blows that can be given by the bare fist or by a Roman bar caestus or by a Greek caestus cannot be given by the modern boxing glove. The movements of the wielder of a glove and hand are slower than those of the wielder of the bare fist; but can be more rapidly carried out than the movements of the wielder of a Greek or Roman caestus. The glove must be manufactured and be fitted to the hand, and a longer time is needed to bring it into action than is needed to bring the bare fist into action; but it is more easily and quickly manufactured and fitted than the later Greek caestus or the Roman bar caestus or the Roman sleeve caestus.

CHAPTER 10

THE KNUCKLEDUSTER

THE ordinary knuckleduster may be described as a metal plate with four holes. The four fingers are placed through the holes; and the insides of the top joints of the fingers are placed on the bottom of the plate which is in the form of a bar. The bar lies in and across the palm at right angles to the forearm, and the finger ends press against the bar. The part of the plate opposite the bar lies over the middle knuckles, and has a wave-like edge, the four crests of the waves being above the four knuckles. The edge forms a set of four artificial knuckles, each artificial knuckle lying over a human knuckle. The form of the artificial knuckles varies. Sometimes the edge is slightly waved, and the knuckles are blunt and not well defined. Sometimes the knuckles are well defined; and sometimes each has a sharp point, *Figure 5 (ii)*. Part of the plate lying between the bar and finger holes is removed to lighten the knuckleduster and preserve its balance. The main features of a knuckleduster are therefore, four projections or wave-like edges, four holes for the fingers, and a bar to lie in the palm, and three metal parts

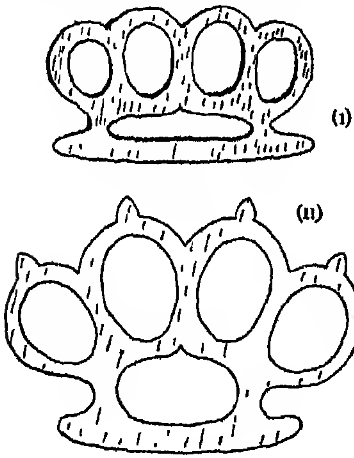


FIG. 5.

(i) Knuckleduster
Warrington Municipal Museum

(ii) Knuckleduster, with four points
Pitt Rivers Museum, Oxford

to lie between the four fingers. When the knuckleduster is held, the hand is nearly clenched with the bar in the hollow or barrel of the fist; and the thumb lies over the forefinger and middle finger.

The fastenings which hold the knuckleduster and the hand together are formed partly by the hand and partly by the knuckleduster. The holes allow the fingers to be passed through them; but only the lower halves of the rings formed by the holes are used as parts of the fastenings, for the lower halves alone are in contact with the insides of the fingers, and the upper halves are not in contact with the fingers. The bar forms a flat surface for the insides of the ends of the fingers to rest upon.

The human and the mechanical fastenings which hold the hand and the knuckleduster together are complementary. The knuckleduster is made of metal and cannot be deformed; and the finer parts of the fastenings must be formed by the hand and fingers. The flesh is deformable and adapts itself to the shapes of the holes and bar and allows the lower halves of the rings formed by the holes to press into the flesh of the fingers, and the bar to press into the flesh of the palm and insides of the ends of the fingers. The flesh partly surrounds the lower halves of the rings and the bar and prevents movement and slipping. The hand and fingers form a pouch for the knuckleduster which corresponds closely in shape to the parts of the knuckleduster which are in contact with the hand and fingers. If the knuckleduster could be removed without altering the form of the pouch, the impressions of the parts of the knuckleduster which had been in contact with the hand and fingers would be clearly seen on the inside of the pouch.

The hand is not fully clenched, because the parts of the knuckleduster between the holes and the bottom of the bar lie within the hand; and the insides of the finger ends are prevented by the bar from reaching the palm, the distance between the finger ends and the palm being equal to the width of the bar. Because the bar lies between the finger ends and the palm the fingers are slightly unclenched, and

the thumb lying over the forefinger and middle finger is pushed slightly outwards.

The knuckleduster is light enough for the contrivance formed by the hand and knuckleduster to be wielded without artificial support being provided for the wrist and forearm, and the fastenings joining the contrivance to the arm are all human. The fastenings which join the knuckleduster to the arm are formed mainly by the fingers passed through the holes and by the ends of the fingers pressed on the bar, and by the connections of the fingers to the arm formed within the hand and wrist and forearm.

The padding between the hand and knuckleduster is formed by the flesh at the insides of the fingers against the lower halves of the rings, and by the flesh at the insides of the fingers against the bar, and by the flesh at the palm against the bar, and by the flesh at the fork of the thumb against the bar. Padding between the outer parts of the finger joints and the upper halves of the ring is unnecessary because the holes are so shaped that the upper halves of the rings do not rest on the joints of the fingers. When the hand is clenched the fork of the thumb presses the bar upwards so that the lower halves of the rings press into the flesh of the insides of the fingers and the top halves of the rings are raised above the finger joints leaving spaces between the upper halves of the rings and the finger joints.

The contrivance formed by the hand and knuckleduster bears many resemblances to the bare fist. Most of the features of the bare fist are reproduced; but the fist formed by the hand holding the knuckleduster is slightly larger than the bare fist, for the fingers are slightly unclenched. The main difference in the form of the contrivance and the form of the bare fist is the presence on the contrivance of the four artificial knuckles lying over or nearly over the middle knuckles. The contrivance is heavier than the bare fist by an amount equal to the weight of the knuckleduster. The parts of the contrivance formed by the artificial knuckles are harder and sometimes much sharper than the knuckles of the bare fist. The fastenings holding the contrivance to the

arm are formed by the skin of the hand and by parts lying within the hand. The parts of the contrivance near the wrist and the wrist of the contrivance are very similar to corresponding parts of the bare fist.

Most of the types of blows that can be given by the bare fist can be given by the contrivance, for the contrivance possesses most of the main features of the fist; but considerable advantages can be gained by directing the artificial knuckles against the opponent, and the contrivance is mainly used in this way. The types of blows given by the artificial knuckles are somewhat similar to those that would be given by the middle knuckles of the bare fist; but the blows are heavier and harder and may be sharper. The blows are heavier because the weight of the knuckleduster is added to the weight of the hand, and harder because the artificial knuckles are harder than the human knuckles, and sharper if the artificial knuckles are pointed. If the edge of the knuckleduster is fairly straight, the blow may not be as sharp as one delivered by the human knuckles; but if the artificial knuckles are well formed and are pointed, the blow may be very much sharper.

When a blow is given by the artificial knuckles the human knuckles do not come in contact with the opponent and are released from the work of directly hitting the opponent. The artificial knuckles protect the human knuckles and replace them for certain types of blows. The artificial knuckles do not partly replace the sides or the flat of the fist or the thumb or any parts of the fist except the knuckles.

The contrivance formed by the hand and knuckleduster forms a single weapon. The hand and knuckleduster are rigidly joined and cannot have independent motions; and the parts of the knuckleduster and the parts of the hand retain their relative positions approximately throughout all movements. The contrivance consists of two main parts. A human part is formed by the hand and an artificial part by the knuckleduster; and the human and artificial parts fit almost exactly and are complementary and together form a weapon.

The size and shape of the knuckleduster are determined within close limits by the size and shape of the hand. The length of the bar is determined by the width of the palm The bar must not project outside the hand, for if a projecting end were to come in contact with the opponent, so much leverage might be exerted on the rings round the fingers that they would cut or damage or sprain the finger joints. The bar must be long enough and wide enough for the finger ends to rest upon it. It must not be made heavier than is necessary to balance the weight of the part above the fingers; and also as little weight as possible must be placed inside the hand to decrease the danger of sandwiching. To decrease the weight within the hand, part of the knuckleduster between the holes and the bar must be removed. The holes must be made rather larger than the fingers so that the top halves of the rings are well above the knuckles when the hand is clenched. The lower parts of the holes must be at a height above the bar to allow the fingers to reach comfortably to the bar in the palm. The upper edge or the points of the knuckles of the knuckleduster must not be made too high, or the leverage when a blow is given may bend the knuckleduster back on the fingers. The holes must be at distances apart which will allow the finger ends to come together comfortably on the bar in the palm. The weight of the knuckleduster must be sufficient to give as much additional weight to the blow as possible; but must not be so great that the wrist and forearm must be supported artificially.

A wooden knuckleduster is used by the Sinhalese of Ceylon, *Figure 6*. It has only three main knuckles, but two small knuckles project from the sides of the weapon. A blow given by either of these side knuckles would evidently be given at right angles to the one given by the knuckles which lie over the human knuckles; and the direction of a blow from a side knuckle is therefore turned through a right angle

Fig. 6.
WOODEN
KNUCKLEDUSTER
Horniman Museum, London

compared with its direction when given by the main knuckles (See Rule 10, Ch. 14).

The fingers are not placed through holes, as when a metal weapon is used, and the spaces between the fingers are not filled. But the wood at three points begins to enter the three spaces between the four fingers, but is not continued to meet the bar of the weapon. In the metal types, the three spaces between the four fingers are filled by the three metal parts which separate the four holes. It will be shown later in the work that the three metal pieces which lie between the four fingers are rifling devices, related to the feathers on the butt of an arrow or to the rifling grooves on the interiors of gun barrels. In the wooden weapon, the rifling devices are in a more rudimentary stage of mechanical development, and appear merely as the three pointed parts at the upper inside of the oval.

The wooden weapon is not in the form of a plate. The bar is somewhat in the form of a cylinder. The upper part is fairly thick, and the knuckles are thick and rounded and not brought to points. A blow given by the three *main* knuckles of the weapon would not be much different from one given by the bare human knuckles, but would be harder. An advantage of using the weapon would be that the wielder's knuckles would be saved from damage. A disadvantage would be that the hostile intentions of the wielder would be revealed by his opponent seeing the weapon fitted to his hand (See Rule 6, Ch. 14).

Crude types of knuckledusters are often used. One type is formed, for example, by a piece of bicycle chain passed round the hand. The human knuckles can easily be mechanized in a rough and ready way by the parts of the chain lying round them, and the bar be formed by the part of the chain within the barrel or hollow of the fist. Another type of knuckleduster is sometimes formed simply by placing three coins, say pennies, between the four fingers, so that they fill the grooves or spaces between the fingers and project to form three sharp knuckles. With this type, the riflings are mechanized by the parts of the coins lying between the

fingers, and the knuckles by the parts of the coins projecting outside the fist. No mechanical bar however is formed, and control over the artificial knuckles is therefore difficult.

CHAPTER 11

THE BAGHNAK

THE Indian baghnak is used to tear or claw an opponent. It is a secret weapon which lies hidden in the hand until it is about to be used.

A common type of baghnak is made of steel and consists of a bar, four claws or blades set at right angles to the bar, and two rings for the fingers, *Figures 7 and 8*. The forefinger and little finger are placed through the rings which are nearly at the ends of the bar. The bar lies in the palm in much the same position as the bar of a knuckleduster. When the baghnak lies hidden in the hand the fingers lie along and over the blades, and the only parts of the baghnak which are visible are the rings on the forefinger and little finger. Each blade somewhat resembles a curved pocket-knife blade The edge of each blade opposite a finger is sharp like the blade of a pocket-knife, and the blade ends in a point.

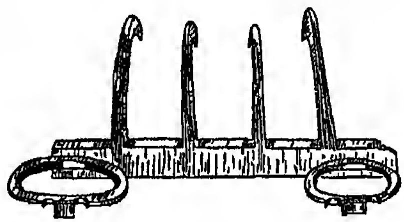


FIG. 7. BAGHNAK
After J. Skelton, F S A., *Antient Armour*

When the baghnak is being used, each finger lies along and over its corresponding blade, *Figure 8* (*ii*). The forefinger lies along and over the blade nearest itself; the middle finger along and over the second blade; the third finger along and over the third blade; the little finger along and over the fourth blade which is near the end of the bar next to the little finger. Each blade forms a support for a finger, and the finger presses the back of the blade to force the point and edge of the blade against the opponent. The size and shape of the baghnak are closely determined by the size and shape

of the hand. The baghnak must not be made so large that it cannot be hidden in the hand. The blades must be made nearly as long as the fingers so that the fingers can lie along and over them and the insides of the top joints can press the blades against the opponent. The blades must be set on the bar at distances apart which will allow the fingers to lie comfortably over them. The rings must be placed near the ends of the bar at a distance apart a little more than the distance between the outer blades, so that the forefinger and little finger may exert some pressure to pull the rings towards each other and so prevent any movement of the bar along its own length. The blades must be curved so that the fingers can lie comfortably over them in positions very much the same as if the fingers alone were used to claw an opponent. The ends especially must be curved so that the finger ends can bend over and exert pressure on them. The blades must be blunt on the edges on which the fingers lie, and sharp on the opposite edges to cut the opponent, and must be curved to a point to tear the opponent.

The fastenings which hold the hand and baghnak together are formed partly by the hand and partly by the baghnak. The rings surround the forefinger and little finger and form closed clasps to hold the baghnak to the fingers. The bar lies across and against the palm and helps to keep the baghnak in position. The backs of the blades are curved to receive the fingers placed over them. Complementary parts of the fastenings are formed by the hand and fingers. A groove running nearly the length of each finger is formed by the back of each blade in the flesh of the finger

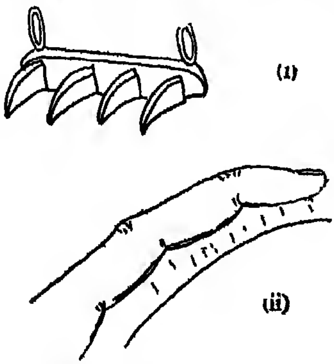


Fig. 8.
(i) Bakhnak
British Museum Handbook
(ii) A finger on a claw of a baghnak

which lies along and over it. The groove is especially deep and well formed at the moment the opponent is clawed, for the back edge of the blade then presses hard against the flesh on the inside of the finger, and the finger then exerts its greatest pressure on the back of the blade. The flesh rises slightly along the sides of the groove and helps to prevent the blade slipping out of the groove and the finger slipping sideways off the blade. Four grooves altogether are formed, one being formed along the length of the inside of each finger. The bar presses against the flesh of the palm and makes a bed for itself in which to lie. The baghnak is made of metal and cannot be deformed by the pressure of the hand and fingers, but is made so that it partly fits the hand and fingers; but the flesh of the hand and fingers is deformable and adapts itself easily and automatically to the shapes of the parts of the baghnak with which it is in contact, and a close fit of the hand and baghnak is obtained. The hand forms a pouch for the baghnak; and if the hand could be removed without altering the form of the pouch, the impressions of the parts of the baghnak which had been in contact with the hand and fingers would be seen on the interior of the pouch. Probably some of the impressions remain on the hand for a few moments when it is removed after use. The impressions of the rings on the fingers especially would be likely to remain for some moments.

The contrivance formed by the hand and baghnak forms a set of claws to claw an opponent; and is partly human and partly artificial. The claws are formed partly by the fingers and partly by the blades. Each claw consists of two main parts. An artificial part is formed by the blade, and a human part by the finger lying over the blade. The blade forms the under part of the claw; the finger the upper part. The finger and the blade are incapable of different movements and together form a rigid claw. The blade partly releases the finger from the work of clawing the opponent, for the finger is released from the need for coming into contact with the opponent and directly clawing him; but indirectly the finger claws the opponent for it is placed behind the blade and goes

through clawing movements, and therefore the blade does not fully release the finger from the work of clawing the opponent or fully replace the finger as a claw.

The baghnak while lying hidden in the hand is loosely held, and the wrist is flexible. During the wielding movements the fingers are set in the form of claws and the wrist is firmly set. At the moment of clawing the opponent, the finger ends press hard on the ends of the blades and the wrist is very firmly set, and the fingers and blades and rings are very firmly fastened together. The weight of the baghnak is not sufficient to demand artificial support for the wrist and forearm, and the fastenings holding the contrivance to the arm are all human. The fastenings holding the baghnak to the arm are formed mainly by the forefinger and little finger placed through the rings and by the fingers placed over the blades and especially by the ends of the fingers, and by the connections of the fingers within the hand extending to the wrist and forearm. The skin plays some part in holding the baghnak to the arm, for when the opponent is being clawed the baghnak tends to move off the fingers, and the skin on the forefinger and little finger is pulled slightly from the hand by the rings and the skin of the hand tightens to prevent further movement. The skin of the palm also tightens at the moment of clawing because the bar tries to move up the hand towards the fingers, and the skin of the palm then helps to hold the baghnak to the hand.

The contrivance when being used against the opponent bears some resemblances to the claws formed by the fingers when the fingers alone are used to tear an opponent. The main and middle knuckles and joints are visible, but the knuckles are not well formed. The top joints and finger nails are visible. The fingers are slightly separated. The back of the contrivance except for the rings closely resembles the back of the hand when the fingers alone are used as claws. The thumb is almost identical with the thumb when the fingers alone form claws. The under sides of the fingers are artificial and sharp. A bar lies across the palm. The fingers

are slightly more unclenched than when they form claws by themselves.

The contrivance when the baghnak lies hidden resembles a slightly unclenched fist; but possesses rings showing on the forefinger and little finger. From the front no parts of the baghnak are visible except the rings; but the end of the bar nearer the little finger may be seen from the side, and the side of the blade nearest the little finger may also be partly seen. The end of the bar nearer the thumb and the side of the blade nearest the forefinger may be fairly well covered by the thumb lying across the hollow of the fist.

Advantages are gained by partly replacing the hand by the baghnak. The human fingers by themselves possess little powers of tearing an opponent, for they are blunt and bend easily. The finger nails are sharp, but are weak and are easily bent or broken when used against an opponent. The blades of a baghnak however can be made strong enough not to bend on being brought into contact with an opponent. They can be made very much sharper than the fingers, and their points very much stronger and sharper than the finger nails. The advantages, however, are accompanied by disadvantages. The fingers are at once available for use as claws; but the baghnak must be manufactured, and must be fitted to the hand, and the method of using it must be learnt. The baghnak may be mislaid and not be available when wanted: the fingers, of course, cannot be mislaid and are always available for use as claws. The hand can be prepared for use as claws without its purpose being known; but the rings on the fingers may reveal the presence of the baghnak. Also the hand when holding a baghnak must be kept nearly clenched, and suspicions may be aroused by the unwillingness of the user to expose his hand and move it freely.

The baghnak by itself is not a weapon. By itself it is an inanimate piece of metal of a peculiar size and shape. Its use cannot be known except by reference to the hand; nor can any reasons be given for its size and shape and materials except by reference to the hand. It possesses no life of its own, and cannot perform any actions against an opponent

by powers of its own, and must remain in the position in which it has been placed until it is moved by outside forces. It could not have been designed and manufactured without reference to the hand, and it was necessary to study the hand closely before it could be designed and manufactured. The baghnak and hand together form a weapon, and the form of the baghnak is complementary to the form of the hand when both are fitted together, and both together form a weapon which comes into intimate working relationships with the wielding machinery formed by the body. The contrivance or weapon requires and demands its own special actions and movements from the machinery of the body when it is being wielded, and the actions and movements of the wielder of a baghnak and hand are differently performed from those of the wielder of a fist or caestus and hand or other weapon.

A flexible type of baghnak possesses five claws fastened to jointed plates of steel which line the palm. Four of the claws are close together and project from the end of the baghnak opposite the wrist, and the fifth claw is fastened to the side of the plates. The wrist of the baghnak has a strap, and there are rings or loops for insertion of the fingers. *

The jointed steel plates cover most of the palm, and four of the claws lie under the fingers, and the fifth claw lies under the thumb. The part of the baghnak opposite the four claws lies under the wrist, and is fastened to the wrist by a strap.

The size and shape of the flexible baghnak are determined within close limits by the size and shape of the hand. The size and shape of the palm determine the sizes and shapes of the plates; and the lengths of the fingers and thumb the lengths of the claws. The sizes of the rings or loops and strap are determined by the sizes of the fingers and wrist.

The fastenings which hold the hand and the flexible baghnak together are formed partly by the hand and partly by the baghnak. The strap forms a clasp shaped like the part of the wrist it surrounds, and helps to hold the baghnak to

* The Rt. Hon. Lord Egerton of Tatton, M.A., etc., etc., *Indian Arms and Armour*.

the wrist. The rings or loops for the fingers also form clasps to help to hold the baghnak to the fingers. The jointed plates impress their shapes on the flesh of the palm, and the flesh of the palm reproduces the forms of the plates and joints. The strap and the rings make beds or grooves in the flesh in which to lie. The human and artificial fastenings are complementary, and the hand and baghnak together form a single weapon.

The fastenings which hold the baghnak to the arm are partly human and partly artificial. The human fastenings are formed partly by the fingers and their connections within the hand and wrist and forearm. They are also partly formed by the skin. The skin is closely attached to the jointed plates, and forms creases to fit into the grooves at the joints between the plates, and the creases and grooves form catches to hold the skin and plates together. If the baghnak begins to move off the hand, the plates of the baghnak straighten and the skin tightens with the movement, and the plates and skin together help to prevent further movement off the hand. The rings also grip the fingers more firmly if the baghnak begins to move off the hand, and help to prevent further movement off the hand. The strap round the wrist also helps to prevent the baghnak moving off the hand.

The jointed plates which line the palm form a kind of artificial skin, and act in much the same way as the skin acts to hold the baghnak to the arm; and the claws of the baghnak project from the plates in a manner resembling the manner in which the fingers and thumb project from the palm. The plates partly replace the skin in the work of holding the baghnak to the arm. They also help to hold the hand to the arm, for when the opponent is being clawed the claws of the baghnak and the fingers tend to pull the hand away from the arm, but the plates tighten and the skin tightens and the plates and skin then help to prevent the hand being pulled away from the arm. The plates partly relieve the human fastenings of the work of holding the hand to the arm.

The claws of the baghnak partly replace the fingers in the work of clawing the opponent, because they partly release the

fingers from the work of coming into contact with the opponent and directly clawing him; and the ends of the claws partly release the finger nails from the work of tearing the opponent. The claws of the baghnak can be made sharper and stronger than the finger and thumb nails; and the contrivance can tear the opponent more easily than the finger nails can tear him.

The contrivance has some resemblances to the fist. All the main features of the fist can be seen. The finger ends and nails can also be seen. The knuckles, however, are not so prominently formed as on the fist. The palm, which cannot be seen in the fist, has an artificial surface formed by the jointed plates of steel. The outsides of the claws are formed by the fingers and thumb, but the insides by the claws of the baghnak. The hand is more unclenched than when the caestus is being held, and the fingers are more separated.

A rigid type of baghnak has three connected steel blades with rings for the insertion of the forefinger and little finger. The three blades lie nearly concealed in the hand when the baghnak is being carried; but when it is being wielded they project from the closed fingers "like the claws of a tiger." [1]

Another rigid type of baghnak has five parallel blades fixed to a bar, with a band to pass round the back of the hand, the band being fastened to the ends of the bar. Two loose rings for the fingers are fastened to the band on some specimens, but not on others. Apparently the thumb as well as the fingers are placed along and over the blades.

Another type of baghnak is made as a pair, one baghnak for each hand. Each consists of four parallel blades set at right angles to a bar. A fifth blade projects from the bar in the direction of the bar and forms a continuation of the bar, and is at right angles to the other blades; and the fifth blade of one baghnak is opposite to the fifth blade of the other of the pair as the thumb of one hand is opposite to the thumb

[1] The Rt. Hon. Lord Egerton of Tatton, M.A., etc., *Indian Arms and Armour*.

of the other hand. The forefinger and little finger are placed through rings, and the four fingers lie along and over the four blades, one finger over each blade. Little information is available about the way this type of baghnak is held. The four blades are of the same length and do not reveal which baghnak is fitted to the right hand and which to the left hand, and it is difficult to know whether the fifth blades lie in the directions of the thumbs or project from the sides of the hands opposite the thumbs. If the fifth blade projects from the side of the hand opposite the thumb, it will not be supported by the thumb and would be used for stabbing an opponent in the way a dagger is used. Much strain would be placed on the four parallel blades if the fifth blade was used in this way, for the parallel blades are fairly loosely set and although able to bear considerable pressure from the fingers pressing directly on them would be easily bent sideways. If the fifth blade lies in the direction of the thumb, the end of the thumb can be placed on the back of the blade to support and drive it against the opponent, and the blade can be used to cut and tear but not to stab an opponent.

The pair of baghnaks bear striking resemblances to the parts of the hand they partly replace as claws. The four blades of each project from the bar in a manner which resembles the way in which the four fingers project from the hand; and the fifth blade projects from the bar in a manner which resembles the way in which the thumb projects from the hand. The baghnaks are not identical, for the edge of the fifth blade of one of the pair faces the opposite way to the edge of the fifth blade of the other.

CHAPTER 12

THE GRIP

WHEN the hand forms a fist the end joints of the fingers lie in the hand or nearly in the hand. The ball of the thumb, or the soft lower inside part of the thumb, covers the end joints of the forefinger and middle finger and third finger; and the end joint of the little finger is partly covered by the part of the palm opposite the ball of the thumb. The middle joints of the forefinger and middle finger lie partly under the thumb and are partly covered by it. The parts contained or nearly contained within the hand are therefore the end joints of the fingers, and the parts contained under the thumb are parts of the middle joints of the forefinger and middle finger. The insides of the end joints of the fingers press against the upper part of the palm near the web of the hand. Pressure from the ball of the thumb also helps the fingers to press against the palm. The thumb exerts some pressure on the fingers and helps to press them against the palm; but the upper part of the thumb rests against rather than presses against the fingers, and does not exert much pressure. The ends of the fingers lie approximately in a straight line which is approximately parallel to the line of the main knuckles and the line of the middle knuckles and the line of the top knuckles; and the line of the finger ends is approximately at right angles to the joints of the fingers and to the direction of the forearm.

When the hand is slightly unclenched a hollow is formed between the fingers and the palm. It is possible to see through the hollow, and it could be nearly filled by a pencil or other thin rod. The pencil or other thin rod would be held approximately at right angles to the direction of the forearm and to the directions of the joints of the fingers; and parallel to the lines of the finger ends and knuckles. The hollow when the hand is more unclenched is filled by the grip of the

handle of the weapon that is being wielded, which may be a part of the hilt of a sword, the handle of a bow, the shaft of a thrusting spear, the handle of a club, etc.

When the knuckleduster is held the hand is slightly unclenched, and the hollow is occupied by the parts of the knuckleduster held within the grasp of the hand, that is by the bar of the knuckleduster and the part of the knuckleduster lying between the bar and the holes. The insides of the ends of the fingers press on the bar of the knuckleduster and press the bar against the palm. The bar lies within the hand, and the finger ends do not quite reach to the palm but *are separated from the palm by a distance equal to the width* of the bar; and the finger ends are pushed slightly out of the hand, and are not covered quite so well by the ball of the thumb and the part of the palm opposite the ball of the thumb. As a result of the bar being within the hand, the hand is partly filled by the bar and the ends of the joints of the fingers are partly pushed out of the hand. The bar releases the ends of the fingers from the work of pressing directly on the palm, and the work of pressing on the palm is directly carried out by the bar. The fingers, of course, still press on the palm, but indirectly through pressing on the bar. The finger ends lie on the bar in a straight line, or in a slight curve which coincides with the direction of the bar. The bar partly replaces the finger ends in the work of pressing on the palm and keeping the fingers rigid; and forms a device similar to that formed by the ends of the fingers. The complete bar of the contrivance is formed by the bar and the ends of the fingers placed on the bar, and is partly artificial and partly human. The bar is also held against the palm partly by the pressure exerted by the thumb and especially by the lower part of the thumb on the ends of the fingers.

The bar is pushed upwards or prevented from moving downwards by the inside of the lower part of the thumb, or the web of the thumb, which pushes the bottom of the bar upwards. Upward pressure must be exerted on the bottom of the bar to keep the top halves of the rings off the fingers.

The parts of the knuckleduster held within the grasp, or

the bar and the part between the bar and holes, form the grip of the knuckleduster.

When a rigid type of baghnak is being wielded the hand is more unclenched than when the knuckleduster is being wielded, and the hollow of the hand is large and is partly filled by parts of the baghnak. The bar lies across the palm in much the same way as the bar of the knuckleduster lies across the palm. The blades also are contained within the grasp of the fingers and hand, and the grip of the baghnak is formed by the bar and the blades. The ends of the fingers are separated from the palm by a distance equal to the distance between the ends of the blades and the side of the bar lying against the palm. The finger ends do not directly press on the palm, but press the ends of the blades and so exert pressure on the bar to press it against the palm. The finger ends are released from the need for coming in contact with the palm by the bar which carries out this work. The finger ends do not lie directly on the bar, but are transferred to places at the ends of the blades opposite the bar and indirectly press on the palm. The finger ends are in a straight line or nearly in a straight line for the ends of the blades are usually in a straight line or nearly in a straight line, and the line of the finger ends is still parallel to the line of the bar; and the lines of the finger ends and of the bar are at right angles approximately to the line of the forearm. The bar of the contrivance is not formed by the bar of the baghnak but by the bar of the baghnak and the finger ends, the finger ends and the bar of the baghnak forming complementary parts of the complete bar of the contrivance. The bar is not pushed upwards or prevented from being pushed downwards by the fork of the thumb but by the forks or webs of the fingers, for movements of the rings up the fingers towards the hand are prevented by the web of the hand, or the forks formed between the forefinger and middle finger and between the little finger and third finger.

When the flexible type of baghnak is being wielded the grip of the baghnak is formed by all its parts except the parts round the wrist. The finger ends do not press directly on

the palm, but indirectly press on the palm because they press on the claws which press the plates against each other and against the palm. The bar of the baghnak is formed by the several plates which lie in directions crossing the palm at right angles approximately to the line of the forearm. The baghnak is prevented from moving up the hand towards the wrist partly by the rings on the fingers and thumb.

When the early Greek type of caestus formed from a thong is held, the grip of the caestus is formed by the part grasped by the hand between the ends of the fingers and thumb and the palm. The ends of the fingers are separated from the palm by a distance equal to the width of the caestus between the ends of the fingers and the palm; and press indirectly on the palm by pressing on the top of the caestus. The thumb also presses the caestus against the palm, but does not exert much pressure but rests against the side of the caestus.

When the later Greek type of caestus is being wielded, the grip of the caestus is formed by the parts of the ring and glove and fastenings held within the grasp. The finger ends press on the flat surface of the top of the ring; and the part of the glove against the palm forms a flattish surface since the palm forms a flattish surface; and the fingers indirectly press the grip of the caestus against the palm. The thumb also helps to press the grip of the caestus against the palm.

When the Roman type of caestus which possesses a metal bar on the back of the hand is held, the grip of the caestus is formed by the parts of the glove and fastenings within the grasp.

When the modern boxing glove is held, the grip is formed by the parts of the glove held within the grasp. If a bar grip is provided, part of the grip is formed by the bar; and the bar corresponds to the bar of the knuckleduster or baghnak, and is at right angles to the line of the forearm. The ends of the fingers do not come in contact with the palm, but are separated by the parts of the glove covering the ends of the fingers. The thumb and especially its lower part helps to press the fingers against the lining of the glove and indirectly against the palm.

When a spherical stone is held, the grip of the stone is formed by the parts within the grasp of the fingers and thumb and palm. The finger ends and thumb end press the surface of the stone opposite the palm and press the stone against the palm. The ends of the fingers are not in a straight line but lie on an arc of a circle, and the end of the thumb also lies on this circle.

CHAPTER 13

GENERAL OBSERVATIONS ON WEAPONS OF THE HAND

A HAND weapon does not form a complete weapon by itself. A complementary part of a hand weapon is formed by the hand; and the hand and the hand weapon together form a complete weapon.

Sometimes a weapon cannot be made except with the hand. The early Greek type of caestus, for example, cannot be made unless the thong is wound round the hand. Sometimes the parts of a weapon cannot be assembled except with the hand. The ring and straps of the later Greek caestus, for example, cannot be placed on the glove unless the hand is inside the glove to give the glove its shape and keep it in shape. The shape of the weapon is sometimes kept by the hand; sometimes the shape of the hand is kept by the weapon. The shape of a caestus, for example is kept by the hand, but the shape of the hand is kept by a rigid type of baghnak. The hand sometimes forms the core of the contrivance, as, for example, when the caestus is used; sometimes the weapon forms the core of the contrivance, as, for example, when the baghnak or the knuckleduster is used.

A single contrivance is formed by the hand and weapon together. The hand is able to come into intimate union with the weapon because it possesses separate fingers each possessing several joints, and flesh which is deformable and can adapt itself to fit the weapon.

The weapon cannot be made of any shape at will, if it is to be a satisfactory weapon. Its form must be complementary to a form of the partly unclenched hand. The form of the hand for any type of hand weapon can be obtained by partly unclenching the hand. If the hand is fully clenched, it forms a fist, and possesses no mechanical parts. If it is slightly unclenched, it forms a complementary part of the knuckleduster. If more unclenched until the main joints and

palm form a flattish surface but the middle and top joints are still nearly unclenched, it forms a complementary part of the caestus. If still more unclenched and the fingers are slightly separated, it forms a complementary part of the baghnak. If yet still more unclenched, it forms a complementary part for a spherical stone.

The mechanical parts cannot be made of any size at will. The size of each part is determined within limits which can nearly always be easily discovered. Each part is related in size to its human counterpart; but is seldom of the same size. Usually a mechanical part is larger or smaller or harder or sharper than its human counterpart.

The fingers are not separately manipulated when wielding a hand weapon as they would be to play the piano or to use a typewriter. Some small movements of parts relatively to each other however are made during the wielding movements. The fingers tighten as the blow is being delivered, but the form of the hand is not much changed. The contrivance can be used only for offensive purposes, and cannot be used for manipulative or other purposes.

Each part of a mechanical weapon corresponds to some part of the fist or claws or to some part of the wrist and arm wielding the fist or claws. A hand weapon cannot have a part which does not correspond to a human part. The human part to which a part of a weapon corresponds can be easily known because, the mechanical part usually occupies a place close to its human counterpart; and resembles its human counterpart; and the mechanical part and the human part together carry out actions very similar to those formerly carried out by the human part alone.

A part of a mechanical weapon may relieve its human counterpart of certain tasks; but the tasks must still be carried out indirectly by the human counterpart. A blade of a baghnak, for example, relieves the finger of the work of coming into direct contact with and directly clawing the opponent; but the finger indirectly comes into contact with and indirectly claws the opponent through the agency of the blade. It appears that no part of the fist or claws can be

fully replaced by a mechanical part or device, and that the mechanical part or device is used merely as an agent to carry out the work of the human part. A mechanical part or device is used by its human counterpart in much the same way as soldiers are used by a general. A general is partly replaced by his soldiers in the work of fighting the enemy. The general does not personally fight the enemy, but indirectly fights the enemy by means of his soldiers. Each soldier is under the general's orders and is directed in all his movements by the general through the agency of officers. The use of soldiers does not dispense with the need for the general, and the general is not less active in fighting the enemy because he uses soldiers; but he is relieved of certain tasks. Similarly, although a mechanical weapon partly replaces parts of the fist or claws, the use of a mechanical weapon does not release parts of the fist or claws from the need for working against the opponent; but parts of the fist or claws may act only indirectly against the opponent through the agency of the parts of the mechanical weapon.

A mechanical part is an imperfect reproduction of its human counterpart, because the human part is only partly replaced, and the mechanical part is distorted so that some advantage for some particular purpose may be gained. The distortion makes resemblance to its human counterpart more remote; but usually some resemblance can be seen, and often the resemblance is very evident.

It is necessary sometimes when partly replacing the fist or claws that parts of the wrist and arm wielding the fist or claws shall also be partly replaced. If the weight of a mechanical part is considerably greater than the weight of its human counterpart, the wrist may be unable to wield the contrivance easily and may need support. Support is given by partly replacing some of the connections between the fist or claws and the arm by mechanical devices like thongs or straps or a glove which may be stronger than the human counterpart or counterparts.

Each type of contrivance requires its own special and distinctive actions and movements from the body while being

wielded; and all actions and movements of the body are affected by the substitution of one type of weapon by another. The actions and movements of the body are quickest when the fists or claws are being wielded, for the hand is not weighted. If the hand is weighted, all the actions and movements of the body are slowed down, and the more the hand is weighted the slower and more deliberate the actions and movements of the body become. The actions and movements of the feet although slowed down when the hand is weighted are still related to the movements of the hands.

Although the various hand weapons have been produced through attempts to replace parts of the fist or claws, probably those who produced them were not aware that they were trying to replace parts of the fist or claws. The forms and sizes and materials of the weapons were discovered by processes of trial and error. No doubt the ancient Greeks tried to vary the size and material of the thong of the caestus. They may have made it longer or stiffer in the hope of being able to inflict harder blows. But the wielder must have found that the longer or stiffer thong hurt or chafed his hand or worked loose or was unsatisfactory in some other way, and the longer or stiffer thong would then have been discarded. Similarly, attempts must have been made to vary the forms and sizes and materials of other hand weapons until the most satisfactory forms and sizes and materials were discovered.

The process of making and developing these weapons may be described as a process of mechanizing the fist and claws, or partly replacing human parts of the fist and claws by mechanical parts. It might seem to be a simple matter to replace parts of the fist or claws by mechanical parts, but it is not so. The mechanical parts must come into harmonious working relationships with the offensive machinery of the body. The weapon may not possess any parts which do not correspond to human parts. The actions of the mechanical parts must be very similar to those of their corresponding human parts. Human parts must be partly replaced without amputation or constriction of the human parts. These and

other conditions must be satisfied before a satisfactory weapon can be produced.

Considerable advantages may be gained by mechanizing parts of the fist or claws. Harder and sharper and heavier blows can be given when the fist is partly mechanized, or the opponent can be torn more easily when the claws are partly mechanized. But no advantage can be gained that is not accompanied by a disadvantage. Increasing the degree of mechanization has the effect of slowing down the movements of the body because of the additional weight of the mechanical parts. It increases the time needed to bring the contrivance formed from the weapon and the hand into action, because of the time required for making and fitting the mechanical weapon. It also produces a loss of flexibility, and the wielder is unable to respond so quickly and easily to the immediate movements of the opponent. A wielder of the fist responds quickly and easily to the movements of his opponent as is shown by the rapidly changing positions of the hands and feet; but the wielder of a partly mechanized fist has more difficulty in responding to the movements of an opponent as is shown by the slower and more deliberate movements of the hands and feet. The wielder of a mechanical weapon would seem to have an advantage over the wielder of the fist or claws; but he has an advantage only if he is allowed a start in time to find the materials for his weapon and to manufacture it and fit it to his hand.

In order to discover how hand weapons originate and evolve it is necessary to study the complete weapons formed by the hand and the weapons. If hand weapons are studied without reference to the complementary parts formed by the hand, essential and main parts of the weapons will not be studied. If, however, they are studied with reference to the fist or claws, it can be seen that they originate as results of attempts to replace parts of the fist or claws; and that new types will appear and existing types develop as results of attempts to replace other or more parts of the fist or claws.

CHAPTER 14

OFFENSIVE MACHINES

THE offensive machine may be defined as the machine formed by the body for offensive actions. The machine may be formed entirely by the body; but its parts can be given artificial extensions, in the forms of weapons; and when a weapon is fitted to the body, the offensive machine then consists of human and mechanical parts.

When the bare fist is the weapon, the offensive machine is formed solely by the body, and all parts and devices of the machine are human. When a caestus, knuckleduster, boxing glove, or other similar type of weapon is used, the offensive machine consists of mechanical and human parts. Similarly, when the human claws form the weapon, the offensive machine is composed only of human parts; but when a weapon like a baghnak is used, it consists of mechanical and human parts.

No new parts or devices are added to the offensive machine when a caestus or baghnak or similar type of weapon is used, for, as has been explained, the mechanical parts are merely crude extensions of human parts. Also, no human part or device is replaced by any mechanical part or device, for the mechanical part or device and the human part or device to which it corresponds together form the complete part or device; and the mechanical extension merely relieves its human counterpart of the task of directly carrying out offensive actions.

Mechanization of a human part or parts distorts the offensive machine, with advantages for certain purposes. Thus, by fitting a knuckleduster the knuckles of the fist can be partly mechanized and distorted so that heavier and sharper blows can be given by the knuckles acting indirectly through the agency of their metal counterparts. Corresponding

disadvantages, however, attend the mechanization of a part or parts of the machine.

The offensive machine when the bare fist is the weapon may, for convenience, be called the bare fist machine, or simply the fist machine. When a caestus is fitted, the machine may be called the caestus machine. When a baghnak or knuckleduster is fitted, it may be called the baghnak machine or the knuckleduster machine. If a club, bow and arrow, or rifle, is fitted, the machine may be called the club machine or the bow and arrow machine or the rifle machine, according to the type of weapon being wielded. And so on, each variety of the machine being described according to the type of weapon being wielded.

As has been pointed out, a multitude of different types of offensive machines can be formed by the body. For example, one type can be formed for delivering a thrust with the fist, another for delivering a hammer blow with the fist, another for delivering a swinging blow with the fist, another for delivering an upper cut with the fist, and so on. Types can be formed for clawing an opponent, one type being formed when the fingers are used in one way, others when they are used in other ways. When a caestus is fitted, only a few types of blows can be delivered, and the caestus machine cannot be used for clawing an opponent. Conversely, the baghnak machine cannot well be used for giving hammer blows or swinging blows. It appears indeed that each type of human machine requires to be separately mechanized.

It is true that some types of the partly mechanized machine can deliver a variety of types of blows. Thus the boxing glove machine can deliver many of the types of blows that can be delivered by the fist machine; but few parts of the offensive machine are mechanized by means of a modern boxing glove, and the parts that are mechanized are only slightly mechanized. If any part of the fist were more highly mechanized, the machine would become a more specialized machine, capable of delivering fewer types of blows, as was discovered by the ancient Romans when they made the caestus with a metal bar or the caestus with a long sleeve.

The offensive machine is indeed mechanized by means of a modern boxing glove only to a degree sufficient to prevent the contestants injuring each other.

When a mechanical weapon is being wielded, the machine consists of mechanical parts formed by the weapon, and human parts formed by the body. When a caestus or baghnak is being wielded parts of the fist or claws are formed by mechanical parts, but evidently most of the wielding machinery is formed by the body.

Parts of weapons are elementary mechanical reproductions of parts of the offensive machinery formed by the wielder's body and are mechanical extensions of those parts. The mechanical parts, it should be understood, are not mechanical copies of parts of the human body, but are merely mechanical copies of parts of the offensive machinery of the body. A distinction must always be made, at least *mentally, between parts of the body and parts of the offensive* machinery of the body. Although, for the sake of brevity and convenience, in this work a part of a weapon may be said to be a copy of a part of the body, it should be understood that more correctly it is meant that it is a copy of a part of the offensive machinery. Thus, the metal claw of a baghnak is not a mechanical reproduction of the finger, but is merely a mechanical reproduction of the device or contrivance formed by the finger for clawing an opponent. The human finger is, of course, much too complex an organism to be reproduced by such a crude device as the metal claw of a baghnak. The claw of a baghnak, however, serves sufficiently well to reproduce the device formed by a finger bent to form a claw.

It might seem an easy matter to study a mechanical weapon; but it is not easy to discover all the parts and devices even of the simplest and most primitive type of weapon. Thus, before being fitted a caestus may appear to be merely a thong; but when the thong has been fitted, as has been explained, the caestus possesses rudimentary mechanical knuckles, rudimentary mechanical fastenings connecting various parts to the fist and wrist, parts and

devices to combine its inner surfaces with different parts of the skin, parts and devices to prevent movement up or down the hand, ventilation devices, and a host of other parts and devices. In previous chapters attempts were made to point out some of the parts and devices of a caestus, but it is improbable that more than a very few of its parts and devices were discovered and pointed out, or that more than a few of the ways in which the mechanical parts and human parts work together were pointed out.

Because each mechanical part of a weapon is an extension of a human part, a study of the parts and devices of a caestus or similar type of weapon gives some information about the parts and devices of the fist and claws. But the study does not directly give information about any human parts and devices except those formed by the fist or claws and certain parts of the arm. To hold and operate the caestus, however, the body must provide a multitude of parts and devices which are not situated near the fist or claws. These other parts and devices are not mechanized, and much information about the ways in which they are formed and operated therefore cannot be obtained. A certain amount of general knowledge about them can be obtained. It can be seen that the base or butt of the caestus machine is formed sometimes by one foot, sometimes by the other foot, sometimes by both feet; that the stock of the machine is formed by the stock of the body; that the sights are formed by devices of the hands, and that the line from one hand to the other at the moment the blow is delivered gives the elevation of the blow, in much the same way as the axis of a gun barrel indicates the elevation at which the shot is fired; that the line of elevation is always approximately at right angles to the axis of the stock, or in other words that the line joining the hands always tends to be at right angles to the stock of the body, the body leaning backwards or forwards as the elevation is increased or decreased; that the movements of the feet are related to those of the hands; and so on. But although a mass of such general observations could easily be obtained, the observations would be unrelated and would not be of much help in

giving an understanding of the construction and working of the human offensive machinery. Only when human parts are partly mechanized can the human parts be effectively studied. Often, indeed, it is difficult to realize a human part exists until it has been partly mechanized and externalized.

It may be helpful to anticipate certain facts and results which will be substantiated later in this work, so that it can be shown how after a study of types of weapons other than the caestus, some understanding can be obtained of the way in which the body of the wielder of a caestus forms the machinery for wielding it.

Mechanical parts of the rifle machine are formed by the parts of the rifle, and human parts by the wielder's body. A rifle possesses a considerable number of parts, among them a stock, butt, heel-plate, barrel, front sight, rear sight, bolt, trigger, trigger spring, and magazine cover. It will be shown later that all these parts have human counterparts, and are merely mechanical copies and extensions of parts of the offensive machinery of the human body. Less difficulty will indeed be found in showing that parts of a rifle are mechanical embryos of parts of the offensive machinery of the body than in showing that parts of less complex weapons like spears, clubs, and knuckledusters, are mechanical embryos of parts of the human offensive machinery.

Although a rifle perhaps has more parts than a caestus or knuckleduster, yet many and indeed most of the parts of the offensive machine that are mechanized by means of a caestus or knuckleduster are not mechanized by means of parts of a rifle. Thus, for example, the skin of the fist is not mechanized by means of parts of a rifle as it is by means of the glove of a caestus. Or again, the human fastenings which connect the wrist and arm are not mechanized by means of parts of a rifle, for the rifle is not bound or tied or attached to the hand by mechanical fastenings after the manner of a caestus, and most of the fastenings which hold a rifle to the body are formed by human parts and devices. In many ways therefore the rifle machine is less highly mechanized than the caestus or boxing glove or knuckleduster machine. But, on

the other hand, many parts of the wielder's body which are not mechanized by a caestus, boxing glove, or knuckleduster, are mechanized by the rifle. Thus, for example, the stock, the butt, the heel-plate, the barrel, and the front and back sights, are partly mechanized in the rifle machine, but these parts in the caestus machine are formed only by human parts.

A weapon cannot be made whose parts are not mechanical copies of parts of the offensive machinery of the body, nor indeed can any weapon have any part that is not a copy of some part of the body. It is true some sort of weapon might be made, some of whose parts might have little or no correspondences to human parts. Such a weapon, however, could not come into general use, and could not be developed. In other words weapons cannot be invented, and no type of weapon has been or ever will be invented. Weapons can be *made and be developed only by mechanizing parts of the* human machinery, and weapons are parts of the offensive machinery which exist outside the body.

The maker of a weapon who fitted a part to it which did not correspond to some part of the wielder's body would be like, say, a tailor who made a coat with three sleeves. A tailor who persisted in inventing parts for a garment which had no human counterparts would soon go out of business; and it can be said that coats cannot be made with three sleeves, that is so that people will buy and wear them. In the same sense it can be said no part of a weapon can be invented, that is so that it will come into general use and be capable of development.

It follows that because parts of a weapon are merely extensions of parts of the human offensive machinery, the number of parts of the offensive machine cannot be increased or decreased. Therefore the number of parts and devices of the caestus machine or knuckleduster machine or boxing machine must be the same as the number of parts and devices of, say, the rifle machine or shot gun machine. If then a part or device of one type of machine can be recognized, it can at once be known that every other type of machine possesses

this part or device, either in human or in partly mechanical form. Thus, for example, since it is known that a rifle has a stock, it can at once be known that the caestus machine has a stock. The stock of the caestus machine however is not mechanized, and is formed wholly by the trunk or stock of the wielder's body. How the body forms a stock for the caestus machine cannot be known, except in a general way, from direct examination of the caestus machine; but certain facts about it can be known when the stock of the rifle machine has been studied. Or again, since it is known that a rifle has a rifled barrel, it can be known that the knuckle-duster, boxing, and caestus machines, have rifled barrels. The ways the barrels of these machines are formed and the ways in which their barrels are rifled will be explained later.

After a study of various machines like the rifle and shot gun machines in which parts formed by the body and arms and legs are mechanized, the caestus machine can be studied again, and some information about the ways in which the body forms the wielding machinery can then be obtained. Still anticipating some later results, a simple example may help to illustrate this. It is not easy to know how the wielder of a caestus aims his blow. But in certain types of crossbow machines a back sight is formed by the knuckle of the thumb of the right hand, and the crossbowman aims by looking over the top of the knuckle towards the front sight. The use of a knuckle of the fist as a back sight suggests, indeed reveals, that in all varieties of the offensive machine, the sights are formed by the knuckles or by mechanical extensions of them. Therefore it can be known that when a blow is given by a fist or caestus, the direction of the blow is along the line joining the knuckles of the hands. When the method of sighting is recognized, it becomes obvious that a blow from a fist or caestus cannot be given otherwise than along a straight line from one hand to the other, for a line can always be taken from one hand to the other towards the point of the blow, since one hand must be in contact with the opponent when the blow is given.

Again, as another simple example, a study of the bow and

arrow or rifle machine at once shows that elevation and depression for the coming shot are obtained by raising or lowering the left hand. Therefore it can at once be known that elevation and depression are obtained, say by a boxer, by raising or lowering the forward hand. Thus, if he intends to hit the opponent higher, he elevates the line joining the hands, and conversely if he intends to deliver the blow lower, he depresses this line. At any moment, the line joining the hands gives the elevation of the intended blow. The frequent and rapid changes of the angle of elevation reveal the frequent and rapid changes of intention of the boxer with regard to the direction of an intended blow or parry.

It may here be pointed out that the parts of the elevating and depressing machinery of the rifle machine are not mechanized; and the elevating and depressing movements are performed by human mechanisms of the rifleman's body. The elevating and depressing machinery is slightly mechanized in some gun machines, for example in the field gun machine, the siege gun machine, and the naval gun machine, for the barrels of these weapons are not elevated or depressed by human mechanisms; and great guns have certain mechanical contrivances to assist in elevating and depressing the barrels. Indirectly and primarily, of course, the barrels are elevated and depressed by the gunners. No offensive machine can be devised that will elevate and depress itself without human mechanisms. Mechanical or electrical contrivances which might seem to dispense with the need for human mechanisms, are mechanical reproductions and extensions of the human elevating and depressing mechanisms as used say when a caestus or rifle is being wielded. Even if, suppose, the human mechanisms were extended to such a degree that a gunner was able to elevate or depress the barrel of a gun by pressing a button, the electrical and other mechanisms which would elevate and depress the barrel would be found after studying them to be merely mechanical extensions of mechanisms of the gunner's body. That this is so is obvious from the fact that if they were not extensions of mechanisms of his body, when he pressed the button nothing could

happen, and his intentions could not be transmitted into action.

Since each part or device of a mechanical weapon is a mechanical reproduction of some part or device of the wielder's body, it is necessary when studying weapons to be able to know as soon as possible to which part or device of the human machine a mechanical part or device corresponds. Often it is possible at once to identify corresponding human and mechanical parts, because of resemblances of shapes or materials. Thus, it can at once be known that the sleeve of a Roman caestus corresponds to the skin of the wielder's arm, for the shape of the sleeve is very similar to the shape of the skin of the arm. Also, the materials of the human skin and of the sleeve are very similar. Or again, the glove of a caestus obviously corresponds to the skin of the hand and wrist, as can be seen from resemblances of shapes and materials.

Correspondence can be deduced in very many cases because the mechanical part is close to its human counterpart. Thus, the glove of a caestus lies over the skin of the hand and wrist, and it follows that the skin of the glove corresponds to the skin of the hand and wrist. The metal knuckles of a knuckleduster not only have some remote resemblances to the main human knuckles, but lie over them, and therefore must be extensions of them. The metal claw of a baghnak not only somewhat resembles the claw formed by a finger, but also lies along and immediately under a finger, and must therefore correspond to the claw device formed by that finger.

The way in which parts of a glove correspond to parts of the skin and to the knuckles, creases, and other parts and devices of the hand or fist, can be well understood by examining an ordinary kid glove such as one wears every day. The glove fits the hand and fingers fairly closely. After being worn for some time, correspondences of various parts of the glove to parts of the skin become still more evident, for many of the creases of the skin of the palm and insides of the finger joints and other parts of the hand become

faithfully reproduced by the glove Each part of the glove corresponds to the part of the skin over which it lies, and each device of the glove is near its corresponding human device. Thus, the fork of the thumb of the glove lies close to the fork of the thumb and corresponds to it; the crease device at the inside of the middle knuckle of the forefinger of the glove which helps to allow the forefinger of the glove to bend lies close to the crease at the inside of the middle knuckle of the forefinger of the hand which helps to allow the human forefinger to bend and corresponds to it; and so on for a multitude of other parts and devices. When the hand is clenched, the exterior of the glove takes the form of the exterior surface of a fist; and many of the features of the human fist are fairly closely reproduced by the glove. Ideally, a glove should be made for the hand that is to wear it; but usually the buyer of a glove takes some trouble when buying it to see that it fits fairly closely, that is, to see that its various parts and devices will after some use come into fairly close correspondences with the human parts and devices of the hand and fingers.

A study of the parts and devices of a glove has never been made. If it were made, it would be found the number of parts and devices was very large, and perhaps a complete list of them could not be made. If also a study were made of the parts and devices of shoes, boots, stockings, and other wearing apparel, it would be found that the rules which describe the processes by which weapons originate and develop would also describe those by which wearing apparel originates and develops; and much new knowledge would be obtained about clothes and the clothing machinery of the body. It is, of course, because the clothing machinery of the body does not operate sufficiently well to clothe the human body with hair, wool, fur, or other type of covering, as it does so well for animals and other creatures, that it is necessary for man to devise artificial or mechanical extensions of the clothing machinery of his body. However, a study of clothes cannot be undertaken in this work.

The human part or device to which any mechanical part or

device of a weapon corresponds can also be known because of similarities of actions of human and mechanical parts or devices. Thus, for example, it can at once be known the thumb of the glove of a caestus corresponds to and is an artificial extension of the skin of the thumb, because the human thumb and the thumb of the glove always move similarly, and the skin of the thumb and the thumb of the glove cannot have different movements. Or, as another example, that the middle knuckle of the forefinger of the glove corresponds to the skin of the middle knuckle of the forefinger, because both have similar movements; and when the knuckle of the glove hits the opponent, the human knuckle is behind it and indirectly and primarily gives the blow. The metal claw of a baghnak corresponds to and is a mechanical extension of the claw device formed by the finger lying over it, because the metal claw and the human claw have similar actions. And so on, in a host of other cases.

Often corresponding human and mechanical parts can be identified because the parts of a weapon are usually in the same relative positions with respect to each other as corresponding parts of the body. Thus the parts of a rifle, shot gun, or crossbow, are nearly all in the same relative positions as corresponding parts of the wielder's body; and if a rifle, shot gun, or crossbow, is placed upright and its parts are compared with parts of the body, the part of the body to which any part of the weapon corresponds can at once be identified. Thus, it will be shown later, the heel-plate corresponds to and is a mechanical reproduction of the sole of the wielder's foot, the butt of the weapon corresponds to the butt of the body, or contrivance formed by the legs of the wielder; the stock of the weapon corresponds to the stock of the body; and so on. A glance at the crossbows shown in Figures 39, 54 will quickly allow the reader to identify corresponding mechanical and human parts.

It will be useful to have the above observations on the ways of recognizing corresponding human and mechanical parts, and certain observations about the ways in which parts

become mechanized, in the form of rules, by the application of which the study of weapons can be facilitated.

RULE 1. A part of a mechanical weapon corresponds to some part of the offensive machinery of the body, and is an elementary copy of it.

RULE 2. A complete part of the offensive machine may be formed by a human part, or by a human part and its mechanical counterpart.

RULE 3. A mechanical part originates as an extension of a human part.

RULE 4. The actions of a mechanical part or device are similar to and extensions of those of its human counterpart.

RULE 5. The mechanical part releases its human counterpart from the task of directly acting against the opponent.

RULE 6. Advantages gained by mechanizing a part of the machine are accompanied by corresponding disadvantages.

RULE 7. A part or device can be transferred to another part in contact with it.

RULE 8. A mechanical part may be transferred from one end of a part to the opposite end.

RULE 9. An action may be transferred from the beginning to the end of a movement.

RULE 10. A part or an action of one machine may be turned through a right angle in another variety of the machine.

RULE 11. A part or an action of a part may be reversed in another variety of the machine.

RULE 12. The reproductive machinery of the body is mechanized simultaneously with the offensive machinery, and to the same degree.

CHAPTER 15

THE CLUB

A CLUB with a roundish head often has some resemblances to a fist at the end of an arm. Such a club is indeed a crude mechanical reproduction of a fist and arm.

The club machine consists of human and mechanical parts. Most of the parts of the machine are formed by the body. All the machinery which wields the club is human and formed only by the body. But the arm and fist of the machine are formed partly by the club. If a one handed club with a roundish head is being wielded, the wielder's arm is given an artificial extension by means of the handle, and the fist is given an artificial extension by means of the head of the club. The handle forms a mechanical counterpart of the arm, and the head a mechanical counterpart of the fist.

The head of the club corresponds to the fist, and the handle to the arm. It can be seen at once, by the application of the Rules, that the head of the club corresponds to the fist and its handle to the arm; for the head has a rudimentary resemblance to a fist and the handle to an arm, and the head and handle together somewhat resemble a fist at the end of an arm (Rule 1); and the movements and actions of the head and handle together somewhat resemble those of a fist and arm (Rule 4). Indeed the movements and actions of the head of the club are at all times similar to those of the partly clenched fist formed by the hand which holds the club, and those of the handle are similar to those of the wielding arm.

The hand as it grasps the handle of a club has the form of a partly clenched fist, the degree to which it is clenched depending mainly on the girth of the grip of the club. When the club is merely, say, a thin cane, such as at one time was

much used for hitting schoolboys, the hand is very little unclenched, and differs little in form from that of the bare fist. The complete fist of the club machine is formed partly by the fist at the grip and partly by the head of the club (Rule 2); and is in two main parts, one part being human and the other artificial.

The head of the club is closely related to the fist at the grip, for, the type of blow given by the head of a club is a type of blow that can be given by a fist; and the head of the club and the fist at the other end of the handle necessarily have similar movements and actions, and indeed cannot have dissimilar ones, for the hand and head are rigidly connected by the handle. Thus, if the hand is raised or lowered, the head of the club is raised or lowered similarly; if the hand is brought back or pushed forward the head of the club is brought back or pushed forward; if the head is stopped suddenly by coming into contact with the opponent, the hand is stopped suddenly at the same instant; and so on. The head of the club, therefore, it can be seen, is closely related to the fist at the grip.

The opponent is directly hit by the artificial part of the fist only, that is, by the head of the club and not by the hand as well; and the human part of the fist is released from the task of directly inflicting the blow and from the need for directly coming into contact with the opponent (Rule 5). Indirectly and primarily, of course, the blow is given by the human part of the fist; for the head of the club cannot take any action against an opponent by itself, and must be moved by its human counterpart.

The actions and movements of the human part of the fist are behind those of its artificial counterpart, and the actions and movements of the head of the club are merely extensions of those of the hand at the grip. Thus, for example, if the hand is swung round the body, the head of the club swings round the body in a similar direction and describes a curve larger than but similar to that described by the hand, the outer curve described by the head being a magnified copy of the smaller one described by the hand. No doubt, when a

club is inexpertly wielded or is not well proportioned in its parts, the curves described by the head and hand are not always exactly similar or perhaps even approximately so. But the more expert the wielder, probably the more closely does the outer curve copy the inner one. According to Rule 4, indeed, the actions and movements of any part of any mechanical weapon and those of its human counterpart are similar.

A club cannot take any action against an opponent unless it is moved and operated by a wielder. Left to itself it will remain where it is, and moulder into dust or rust. Nobody has ever been hit by a club, or other weapon. It is the wielder of the club or other weapon who hits the person, as is recognized in a court of law. Judge, jury, and all others in court, accept as an obvious fact that an injury done to a person through the agency of a weapon is primarily caused by the wielder who is fully responsible for its actions and movements The theory on which this work is based, viz. that parts of weapons are merely extensions of parts of the wielder's body and merely allow his actions and movements to be extended, can thus be seen to be neither original nor revolutionary.

The head of the club is not close to its human counterpart, for the reason that it is in a transferred position, having been transferred from the hand at the grip to the end of the handle opposite the grip, in accordance with Rule 8, which says a part or device of a weapon can be transferred from one end of a part of the machine to the other; and the mechanical part of the fist has been so transferred that it is separated from its human counterpart by the length of the handle of the club.

The fact that the head of a club is separated from its human counterpart reveals that it is not the earliest mechanical form of the fist. According to Rule 3, the mechanical fist must have originated close to the human fist as an artificial extension of it. Primitive types of the mechanical fist can be seen in the caestus, modern boxing glove, and knuckleduster, and stone held in the hand for clubbing an

opponent. These weapons, as has been shown, are forms of the fist, in the first stages of emergence as mechanical extensions of the fist.

The mechanical part of the fist of the club machine is not always fully transferred. Indeed very often part of it is left near the hand, to allow the hand to obtain a better grip or to prevent the weapon slipping from the hand. The untransferred part often takes the form of a swelling or knob or rim. It can be well seen in Figures 10, 11, 12, 13, 19 Probably, in some cases, the proportion of the fist that can be transferred is governed to some extent by the need for correctly balancing the club.

The mechanical part of the fist is not transferred at all in some types of tools and instruments and weapons. Thus, a kitchen poker often consists of an iron knob at the end of an iron rod. To stir the fire the knob is held in the fist and the end of the rod is pushed among the coals. The knob and the hand around it form the fist of the implement, and the iron rod forms an extension for the forearm. The knob is a crude mechanical reproduction of the fist as is shown by its being held in the fist (Rule 7), by its shape which somewhat resembles a fist (Rule 1); and so on. No part of the fist is transferred to the end which stirs the fire, for this part does not end in a knob or rim but usually ends in a point. When a walking-stick has a knob for its head, the knob is held within the human fist, and is not transferred to the end which makes contact with the ground. If it were used as a weapon, it could be used either by leaving the head untransferred or by transferring it. That is, the wielder could retain the knob in his hand and hit or thrust at the opponent with the other end; or he could grasp the stick at the other end and turn it into a club with a knobbed end. The process of transference would then be seen. The knob, or mechanical part of the fist, would go to the end of the handle opposite the hand (Rule 8), and the direction of the stick would be reversed (Rule 11). The kitchen poker could similarly be reversed, so that the mechanical fist, formed by the iron knob, could be used to break large lumps of coal; and as the poker

was reversed its head would be transferred to the end of the poker opposite the hand.

Saucepans, frying-pans, tennis rackets, cricket bats, hockey sticks, and many other tools and implements, often have knobs or rims more or less prominently formed at the ends of their handles; the knobs or rims being mechanical parts of the fist not transferred away from the fist which holds the tool or implement.

When a club has no knob, rim, or similar type of device, at the end of the grip, it seems the mechanical part of the fist is fully transferred Thus, the club in *Figure 9* has no knob at the grip, and the mechanical part of the fist is fully transferred.

The mechanical or artificial part of the fist when transferred to the end of the handle opposite the hand can be considerably distorted, for it is then freed from many of the conditions preventing distortion which are imposed when it is not in a transferred position and is held directly by the hand. Limits are set to the size of a roundish stone held in the hand and used as a club, for if the stone is too large it cannot be held, and if too small cannot be effectively used as a club. The head of a club is indeed often distorted to such an extent that resemblance of shape and size to the shape and size of the human fist can sometimes hardly be seen.

The head of a club can be made harder and heavier than the fist, and harder and heavier blows can be given by the head than can be given by the bare fist. Conversely, the head can be made lighter, and a blow having considerable velocity as a result of the extra leverage allowed by the use of the handle can then be delivered. Thus, when a light cane is used, part of the cane automatically forms an extension for the wielding arm, but the head being merely the part of the cane that hits the opponent and being very light can be given considerable velocity; but although the blow will be light it may be sharp and may even cut. By making the head of a club of iron or steel, a mace or other type of club can be formed, with which the mail armour of an opponent can be smashed.

A club with a wooden head or one consisting of a cane or straight stick is almost useless against an opponent in steel armour. A type of club for use against knights in armour is the mace, whose head sometimes consists of a heavy metal ball. With this type of club the steel armour can sometimes be smashed or damaged. The knight's armour is an artificial and mechanical reproduction and extension of his skin, which relieves his skin of the need for directly receiving the blow or thrust of an opponent, unless the blow or thrust is so heavy or keen that it breaks or pierces the artificial skin. A study of armour lies outside the scope of this work; but it can be pointed out that the ways in which armour originates and develops can easily and quickly be known by using the methods of this work, and with the help of rules similar to those given for weapons

The arm of the club machine is in two main parts, a human part being formed by the wielder's arm and a mechanical part by the handle of the club. The hard parts are formed partly by the wielding arm and partly by the handle; but the soft or flexible parts only by the wielding arm, for the handle has no soft or flexible parts, and therefore can be a reproduction or extension only of the hard parts of the wielding arm. The handle forms an artificial extension for the wielding arm, and the length of the arm of the machine is equal to the length of the human and artificial parts together, the artificial part being placed in a line, or end to end, with the human part (Rule 3). The handle of a club thus differs from, say, the sleeve of a caestus, which is a mechanical reproduction of soft parts, mainly of the skin, of the wielding arm and lies alongside the wielding arm. Parts of the sleeve of the caestus are close to their human counterparts, overlying them; but parts of the handle of a club extend outwards from the wielding arm as an extension.

Comparing the girths of parts of the arm and handle it can be seen that usually the handle is reversed compared with the arm. The arm increases in girth, very irregularly, from the wrist to the elbow or shoulder, but usually the handle increases in girth from the grip to the head. But the handles

of some clubs are thinner near their heads, the handles of some varieties therefore being reversed compared with those of other varieties (Rule 11).

The lengths of the handles of clubs are probably related to the lengths of the forearm, whole arm, both arms end to end, or both arms side by side, as can usually be seen from the methods of wielding the clubs. A club with a short handle is usually wielded mainly with movements and actions of the forearm, thus revealing it is related especially to the forearm (Rule 4). The handles of clubs which are wielded with movements of the whole arm correspond to the whole arm, and are related in lengths to the lengths of the forearm and upper arm together. Clubs with very long handles usually are wielded with both hands, and their handles correspond to both arms, or parts of both arms, placed end to end. Clubs with stout and heavy handles which require to be wielded with both hands have handles which correspond to the contrivance formed by both arms placed side by side. But the weight and shape and size and materials of the head affect the length of a handle, for head and handle must balance well, and distortion of the head may also prevent close correspondence between the length of the handle and the length of its human counterpart.

A short, heavy club wielded by both hands is really a doubled weapon. The maker does not make two handles, each corresponding to an arm, and provide two heads each corresponding to a fist, and try and tie them together to form one handle and one head. Instead he makes a thick handle from about the same amount of material as would be needed to make two single handed club handles, and similarly makes one large head equal to about twice the size of a head that would be needed for a one handed club. For example, the maker of a double handed metal mace, instead of making two shafts and welding or tying them together uses the material to make one thick shaft, and instead of making two heads makes one large one. A short and heavy double handed club therefore has a handle which corresponds to the

contrivance formed by both arms, and a head which corresponds to both fists.

The hand and fingers as they grasp the handle form a contrivance to contain and hold the handle, and the contrivance takes the shape of the handle. If the grip is cylindrical, the hand and fingers become deformed to its shape as they grasp it, and automatically parts of a cylinder are reproduced by the insides of the fingers and palm where they are in contact with it; and the human parts of the cylinder and the handle fit very closely. But whatever the shape of the grip, the form of its surface will necessarily and automatically be reproduced in the skin and flesh of the hand and fingers, so that a close fit of hand and fingers and handle is made.

The fastenings which hold the hand and handle together are partly human and partly artificial. It is difficult, in the club machine, to distinguish the cylindrical pouch or barrel contrivance formed by the hand and fingers from the clasp contrivances formed also by the hand and fingers; but in a general way it can be said the fingers form human clasps to surround or partly surround the grip; and the creases on the interior of the fingers, and the grooves between the fingers act somewhat after the manner of treads of rubber tyres of vehicles to help to prevent the handle slipping from the hand. Friction is exerted between the interior surface of the pouch and the exterior surface of the grip, the amount depending mainly on the nature and materials of the surface of the grip and the pressure of the hand. Projections on the surface of the grip make depressions in the flesh of the hand and fingers and fit into them; and the flesh presses into depressions in the grip and fits into them; and catches and other devices are automatically and quickly formed by projections and depressions to help to join the hand and handle.

The human fist is joined to the wrist by very complicated fastenings, formed by sinews, tendons, veins, skin, and other components. The head of the club is also joined to its handle by fastenings, which however are usually of a very simple and primitive type, which imitate their human counterparts only very remotely. When a club is made from a single piece

of material, say wood, the fastenings which join the head and handle are in a very elementary stage of development; and correspondence to the human fastenings which join the wielding arm and fist cannot easily be seen. But when the head is made separately from the handle and is joined to it by thongs or other devices, some rudimentary correspondences begin to become evident. If the fastenings are of leather or skin, correspondences of materials to some of the materials of the human counterparts become more evident, for the fastenings which join the wrist and arm are partly formed of skin. In any well made club, thong fastenings are not arbitrarily arranged according to the maker's whims and fancies, but are arranged as his experience and the experiences often of many generations of club makers before his time have taught him are the best for that particular type of club; and therefore there is likely to be some correspondence between the arrangements of the human and mechanical fastenings. Anatomical dissection of the human and mechanical fastenings would not necessarily prove either that correspondence of arrangements exists or does not exist; for the mechanical fastenings are probably in too primitive a stage of development for correspondence of arrangements to the human fastenings to be seen. Also, the mechanical fastenings do not correspond to the human wrist fastenings formed by the body to join the hand and arm but to the fastenings formed by the body to join the hand and wrist for the wielding of a weapon.

Just before the fist delivers a blow the wrist is firmly set, and fist and forearm become rigidly connected. But during the wielding movements the wrist is more relaxed, and the fist and arm may have some relative movements. The heads of most clubs are rigidly joined to their handles at all times, and the heads cannot have any movements distinct from those of the handles. The heads of some types of clubs, however, notably war flails (*Figure 13*), morning stars, and holy water sprinklers, which are joined to their shafts by thongs or chains, do move relatively to their handles.

Flexible and cord-like components of the wielding arm are

given mechanical extensions by means of the thongs or chains of war flails and similar types of weapons. When the weapon has a stiff shaft and a thong with a roundish object at the end, the shaft is an extension of the hard components of the wielding arm and the thong an extension of the flexible components. The head, of course, is an extension of the fist. The fist is successively transferred, from the human fist at the grip to the end of the shaft, and then to the end of the thong opposite the shaft. The thong does not extend directly from the wielding arm, but is transferred to the end of the shaft, and extends from the shaft. War flails and similar types of weapons, although popular at one time, have never been as much used as clubs with rigid handles; and it seems that the rigid and flexible components of the wielding arm cannot very satisfactorily be mechanized and externalized by being placed end to end as extensions of the wielding arm, with the fist partly transferred to the end of the thong.

The thong of a war flail when made of hide or leather has some correspondence of materials to the materials of the flexible components of the arm; but when the flexible extension is formed by a chain (*Figure 13*), correspondence of materials is remote, but some correspondence between the movements of the chain and those of the arm can be seen.

The handles of some clubs are provided with a thong in the shape of a loop, which loosely surrounds the wrist, and prevents the weapon being knocked away, or allows it to be carried conveniently ready for use (see *Figures 11 and 15*). From the position of the thong, it is evident it corresponds to fastenings connecting the fist and arm which have not been transferred away from the wrist with the fastenings which join the head to the handle, if there are any. They also correspond to the part of the thong of a caestus bound round the wrist and to the tape of a boxing glove.

At the moment a club hits an opponent usually the arm and handle are about in the same straight line. At the beginning of the delivery of the blow, however, the handle may be about at right angles to the arm. The wrist acts as a kind of hinge, and the handle can be turned through about a right

angle from the line of the arm. As a blow is being delivered therefore usually the handle is turned approximately through a right angle, the turning through a right angle being performed as quickly as possible. The handle is turned through a right angle in accordance with Rule 10. Often, as will be seen later, mechanical parts in one type of machine are turned through a right angle compared with their positions in other machines, and may be set permanently in those positions, or always held in those positions. To anticipate, two simple examples will be given to illustrate this turning of parts through a right angle. The bow and strings of the bow and arrow machine are nearly always held in a vertical plane, but the bow and strings of the crossbow machine are held in a horizontal plane. The bow and strings of the crossbow machine, therefore, compared with those of the bow and arrow machine are turned through a right angle. Again, the plane of the forefinger of the rifleman as he pulls the trigger is at right angles to the plane containing the trigger, which it will be explained later is a mechanical extension of the device formed by the forefinger, and the trigger is turned through a right angle compared with the forefinger device.

No part of the club replaces any human part. The fist of the club machine is formed by the head and by the fist at the grip; and the fist and head must perform similar movements and actions. The handle of the machine is formed by the handle of the club and by the wielding arm, which work together to wield the composite fist. It will become apparent, as this work proceeds, if it has not already become apparent, that no part of any weapon can replace any part of the human offensive machine, and that a part of a weapon acts merely as an extension of its human counterpart and allows the actions of the human part to be extended (Rules 3 and 4)

Advantages for special purposes can be gained by fitting a club to the wielder's body. Because the arm of the machine is provided with an artificial extension, the range of the wielder of a club is greater than that of the wielder of a bare fist, and the opponent can be hit when at a greater distance. Greater leverage can be exerted on the artificial part of the

fist by the handle and arm than on the bare fist by the arm alone; and the head of a club can be given greater velocity than the fist when a hammer or swinging type of blow is given. But the advantage of greater leverage is not obtained if a straight thrust is given by a club; and thrusting clubs, perhaps for this reason, are comparatively rare. Since the artificial part of the fist alone comes into contact with the opponent, the human part is saved from damage. These and other advantages are accompanied by corresponding disadvantages (Rule 6). The club must be manufactured, and be fitted to the hand. More time is therefore needed to bring the club machine into action than the fist machine. The club may be mislaid and not be available when wanted. When being used it may fall from the hand and the wielder be disarmed. The movements of the wielder are slower and more deliberate than those of the wielder of a fist, and the opponent can more easily see the preparations for a blow and avoid it than when the fist is the weapon. If the wielder of a club misses his opponent, he is longer in recovering for the next blow. He cannot respond so easily and quickly to the movements of his opponent. And so on. There is no evidence to show that the use of a club, or indeed of any other type of mechanical weapon, gives any absolute advantage, that is an advantage unaccompanied by a corresponding disadvantage, over the wielder of a fist or other human weapon.

In the above discussion of the club machine it has been assumed the head of the club is roundish in shape; but the heads of many clubs are not even approximately spherical. When the head is roundish, it is fairly obviously a crude mechanical representation of the fist. But a flattish head cannot be a mechanical representation of the fist, even allowing for considerable distortion. A club with a flattish head is probably a mechanical representation and extension of the weapon that can be formed by the flat hand with fingers closed. Like the human weapon, it can be used to give either a blow with the flat surface, which would be a kind of smack, or a blow with the edge which would tend to be a cutting blow. A thrust could also be given with the point or end.

Some clubs do not possess a defined head. Such clubs perhaps correspond to the weapon that could be formed by the arm, the fist or hand not coming into contact with the opponent. Such a weapon gives a slashing or cutting blow. A cane or stick without a head is this type of club.

It is possible, although the author is unable to state this definitely, that some clubs, like the New Zealand patu, are mechanical extensions of the arm and shoulder. The shoulder is seldom used as a weapon in warfare, but is much used in some games, as for example, in Rugby football, in which players in the scrum push their opponents with the shoulders and arms.

Some special types of clubs will now be examined, and attempts made to discover corresponding mechanical and human parts.

* * * * *

1. *A stick with a knobbed end* (*Figure 9*).

The stick is held at about A, and this part therefore forms the grip. When the grip is of small girth, the hand is nearly fully clenched, and the fist is almost fully formed. If the grip is larger, the fist is correspondingly less clenched and more open. The grip fits into and fills the barrel, or hollow, of the fist; and lies across the palm, at right angles to its length.

FIG. 9. STICK WITH KNOBBED END

The handle is formed by the part of the stick between A and C, and gives the wielding arm an artificial extension. The position of the grip and the length of the handle can be varied by grasping the stick higher up or lower down; and the length of the handle depends on where the grip is formed.

The knob at B forms the head. The head is a crude artificial or mechanical reproduction of the partly clenched fist at the grip; and the fist at A and the head at B together form the complete fist. The artificial part of the fist is not near its human counterpart but is transferred from A to the opposite end of the handle, to B (Rule 8).

Any kind of knob can form a mechanical counterpart of the fist at A; but for the head to come into close correspondence with its human counterpart certain conditions clearly must be fulfilled. Thus the fist at B must balance its human counterpart, and therefore must be of a certain size and weight, and at a certain distance from the human counterpart, and so on. A wielder usually selects a stick whose head does balance his fist, or trims and shapes the head and handle until fairly close correspondence of human and mechanical parts is obtained.

The head is rigidly joined to the handle at C. The part C, since it joins the head and handle, must be a mechanical extension of the wrist transferred to the end of the handle opposite the wrist. But there is nothing to show the limits of this part, and it is a most rudimentary copy of the wrist device; and correspondence of the mechanical fastenings which join the head to the handle and those which join the human fist to the wielding arm is very remote.

2. *Life Preserver* (*Figure 10*).

The specimen shown is made of wood, but the head is loaded with lead. Its total length is about 10 inches.

FIG. 10. LIFE PRESERVER *Horniman Museum*

The head, the handle, and the grip are clearly defined, and their limits can be seen. The grip is related in length to the length of the hollow, or barrel, of the fist. The shape of the barrel formed by the hand is determined by the shape of the grip of the weapon, and the hand conforms automatically to the shape of the grip. The barrel formed by the hand is therefore not cylindrical, but is larger in girth at the middle than at the ends. The handle increases in girth towards the head; and is reversed compared with the forearm which increases in girth, although irregularly, from the wrist to the elbow. Since the arm increases irregularly in girth, the handle is a distorted copy of its human counterpart. That the handle is a reproduction of the forearm is evident from the fact that the

weapon is wielded mainly with movements of the forearm, and is about the length of the forearm. The head is made heavier by being weighted with lead, but this distortion of materials and weight, although it allows a harder and heavier blow to be given, prevents the weapon being moved as quickly and easily as if it were unweighted. The head is clearly a crude mechanical copy of the fist. The artificial part of the fist is not fully transferred, for there is a smaller copy of the fist at the end near the grip.

The head is fastened to the handle and the handle to the grip by rigid fastenings formed by the wood which is continuous. Although the joints are plainly indicated, correspondence of mechanical and human fastenings is remote.

3. *Constable's Staff* (*Figure 11*).

FIG. 11. CONSTABLE'S STAFF *Horniman Museum*

Constables' staves vary in length, usually from about 10 inches to 2 feet 6 inches, the smaller sizes sometimes being called "pocket sizes". The illustration shows one issued to special constables in London during the war of 1914-1918. It is made of wood and in one piece, and is about fifteen inches long. It has a shaped grip, and a leather thong to surround the wrist loosely.

The grip is so made that each of the four fingers lies in and partly round a groove. Each raised ring of wood formed between each groove of the grip lies between two fingers, and partly fills the groove between them. Each of the rings is evidently complementary to the groove between the two fingers between which it lies. One of its purposes is to prevent movement of the fingers up or down the grip. These raised rings, it will be shown later in this work, form rudimentary rifling devices. The rifling devices are not in the form of spirals, for the plane of each ring is at right angles to the axis of the staff.

The grip is therefore approximately in the form of a cylinder, with rifling devices on its surface. These rifling devices fit into the grooves in the human barrel between the fingers, and are complementary to and counterparts of the grooves. The mechanical rings project from the grip; but the human grooves are depressions in the human barrel; the rings being reversed types of devices compared with the human grooves (Rule 11). Hence the interior of the human barrel is rifled by the three grooves or spaces between the four fingers, and the grip of the staff is rifled by the rings which project from its surface.

The head of this club is not clearly distinguished from its handle, and it cannot be known exactly where one begins and the other ends, and indeed the position of the head and length of the handle depend on the part of the staff which is used for hitting the opponent.

The thong helps to connect the grip to the wrist; but only when the staff is being carried or is knocked from the hand; and correspondence to the human fastenings which hold the fist to the wielding arm is remote.

The staff is meant for use at close quarters; and is wielded usually with actions and movements mainly of the forearm. It is therefore related chiefly to the forearm, as is also evident from its length, which is about the length of an average forearm. Quick and fairly heavy blows can be given with it. It can also be used as a thrusting club. As there is no distinct head, it is possible the main part is a mechanical extension of the forearm only, which would account for its being suitable for giving thrusts as well as blows.

4. *Life Preserver, with jointed head* (*Figure 12*).

The weapon, which is about sixteen inches long, is of wood, except for a hide or leather thong connecting the handle and head. The grip extends for some considerable distance along the handle, perhaps so that the hand can hold the weapon higher up or lower down as required. The

FIG. 12.
LIFE PRESERVER, WITH JOINTED HEAD
Horniman Museum

grip has twenty rings chiselled round it at regular intervals, forming twenty-one grooves. The grip therefore is approximately in the form of a rifled cylinder, but the rifling is not spiralled, for the plane of each ring is at right angles to the axis of the grip. The rifling is too close for the fingers to fit into the grooves between the rings.

The handle is in one piece and rigid, and is of very irregular shape, but the reasons for its irregular shape are not very apparent. The head is of the ball type, and is clearly a mechanical form of the fist; but the artificial part of the fist is not fully transferred, and much of it remains untransferred as the knob near the hand.

The head is connected to the handle by a flexible thong of leather or hide, T, about three inches long. This thong allows the head to move relatively to the handle, as the fist can move relatively to the arm. Since it joins the head and handle, it must be a mechanical reproduction of the human fastenings which join the fist to the wielding arm. It forms a kind of flexible wrist, transferred from the wrist to the end of the handle. There is some correspondence between its materials and those which join the fist to the arm, for it is made of leather or hide and therefore has some resemblances to the skin which joins the fist and arm. Some correspondences of actions and movements can be seen also, for the thong reproduces distantly some of the actions and movements of the wrist as the weapon is being wielded.

The weapon was used in Sheffield in 1870.

5. *Mace, used by knight in armour.*

When a knight in full armour grasps a steel mace, the fist at the grip is partly mechanized by means of the gauntlet, or armour of the hand and fingers.

The fist at the grip is in two main parts. A human part is formed by the partly clenched hand and fingers, and a mechanical part by the steel gauntlet.

The surface of the composite fist at the grip is formed almost entirely by the gauntlet, and the surfaces of the knuckles, joints, and other parts and devices are formed by

the gauntlet. The composite fist is larger than the fist of the ordinary fist machine, for the hand and fingers are partly unclenched to enclose the handle of the mace, and the exterior surfaces of the hand and fingers are increased in size by the gauntlet.

Corresponding human and mechanical parts can easily be recognized. The first finger of the gauntlet corresponds to the skin of the first finger, because it lies over it; the second finger of the gauntlet similarly corresponds to the skin of the second finger, and so on. The middle joint of the little finger of the gauntlet corresponds to the skin of the middle joint of the little finger; the middle knuckle of the third finger of the gauntlet corresponds to the skin of the middle knuckle of the third finger; and so on. Indeed, each part or device of the gauntlet corresponds to the skin of the part of the hand or fingers over which it lies. So obvious are corresponding parts and devices that a child could at once point them out.

The handle gives the wielding arm an artificial extension. The wielding arm is partly of steel, since it is armoured, and there is continuity of materials from the wielding arm to the head of the mace.

Often the head of a mace consists of a metal ball or sphere, and sometimes spikes or blades project from it. A hammer blow or a swinging blow is given; and it is fairly evident the head is a mechanical extension of the fist at the grip transferred to the end of the handle; and the material of the head may be the same as some of the material of the fist at the grip. Thus if the gauntlet is of steel and the head of steel, parts of the fist at the grip and the fist formed by the head are of the same material.

When a spherical stone is held in the hand and used as a club, the fingers curve partly round the stone and lie on its surface. The spikes of a mace's head do not, however, lie on its surface, but project at right angles to it. The spikes are probably mechanical reproductions of armoured fingers transferred to the head and then turned through right angles (Rules 8 and 10), so that they lie along radii instead of along

the surface of the ball or sphere, and become extensions of the radii.

It is not easy to understand how the blades of a mace have originated, or to find their human counterparts, but the following suggestions may help to solve these problems.

The actions of the mace can merely extend actions of the wielder, as is evident since a mace cannot take any actions by itself. Therefore the actions of the blades merely extend certain actions of the fist at the grip. A kind of blade is formed by the edge of the gauntlet, along the little finger and edge of the palm. No doubt, in an emergency, say if the knight lost his mace, he would use his armoured fist, or with the open armoured hand could cut or slash an opponent with the edge of the gauntlet. A blade of the mace may be this edge device of the gauntlet copied and distorted in form and transferred to the head of the mace. Distortion would easily allow four or more blades to be provided instead of one, although usually only one blade at a time could be directed against the opponent.

6. *Iron War Flail* (*Figure 13*).

This weapon is entirely of iron. It consists of a handle about 18 inches long, a chain about a foot long, and an iron ball with six spikes projecting outwards and a longer spike projecting downwards.

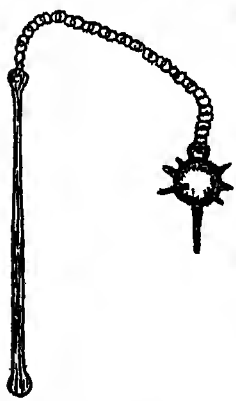


Fig. 13.
WAR FLAIL
Horniman Museum

The handle is a mechanical extension of the contrivance formed by the rigid parts of the arm. The chain is flexible, and is a crude mechanical extension of the flexible parts of the arm. Correspondence of materials is very remote, for the rigid parts of the wielding arm are of bone and the flexible parts of sinew and similar materials, but the rigid and flexible parts of the weapon are of iron. In many flails the flexible extension is of leather or hide, and correspondence of materials is closer.

Neither the handle nor the chain lies alongside the wielding arm. The handle extends outwards as an extension of the rigid parts of the wielding arm, so that it is end to end with them. The chain does not extend immediately from the flexible parts of the arm, but is transferred to the end of the rigid extension, or handle.

The head is a mechanical counterpart of the fist transferred to the end of the handle, and transferred again to the end of the chain. It can be noticed that the mechanical part of the fist is always transferred to the end of a part and never say half or one third or one quarter the way along it. Clearly in the ordinary club machine, the head could not usefully be placed half or one third the way up the handle. Similarly, the head of the flail could not usefully be transferred say to a place one third the way up the handle, or one third the way along the chain. It seems indeed to be a general rule that parts or devices can be transferred only from one end of a part to the other end. The ways in which parts can be transferred can be well seen from a study of clubs and flails.

The artificial part of the fist is not fully transferred for there is a rim or knob just below the grip, or rather the major part of the artificial fist is transferred to the end of the chain and a small portion is transferred to the end of the handle by the grip. One purpose of the rim or knob is to help to prevent the handle slipping through the barrel of the hand, for the handle of the club machine does not move through its barrel unless the club is thrown. Another purpose probably is to help to balance the head of the flail.

The spikes apparently are mechanical reproductions of fingers transferred to the head of the flail and turned through right angles, so that instead of lying round the surface of the ball as fingers lie round a ball held in the hand, they project outwards. The longer spike is at right angles to the other six spikes, and is perhaps a mechanical counterpart of the thumb, which when the hand is opened can be placed at right angles to the fingers. Distortion of the number of mechanical fingers to six gives the advantage that the ball need not be directed, and one metal finger is

certain to face the opponent. Distortion to provide a greater number of fingers, or spikes, than the hand possesses, makes correspondence more remote and therefore introduces disadvantages, one being that six spikes are heavier than four unless they are made thinner, and another is that six spikes are more difficult to fit than four. If the process of distortion of numbers were to be carried too far, the spikes would eventually become so numerous and thin that a brush would be formed, and an opponent hit by a head provided with a brush would feel little inconvenience. It is evident that a broom or similar type of household implement has been developed by mechanizing the fingers and distorting the number of mechanical fingers, and then transferring the mechanical fingers to the end of the handle opposite the hands, the bristles or hairs of the broom's head being types of mechanical fingers. Distortion of numbers of fingers makes the implement very useful for sweeping a floor, but useless as a weapon. If conversely fewer mechanical fingers are provided than human fingers, the mechanical fingers can easily be made stronger. If all the human fingers are mechanized into a single finger which is then transferred to the end of a shaft a spear with a single point will be produced.

The metal eyes which join the chain and handle and the chain and head, serve much the same purpose as the joints of the elbow and wrist, and allow extensions of their movements (Rule 4). One metal eye is transferred to the end of the handle and the other to the end of the chain.

The human fist can twist relatively to the upper arm through about two right angles, mainly through the actions of the joint of the elbow; and it can bend but not twist relatively to the forearm through about one right angle. These twisting and bending movements cannot be magnified by means of the handle, for the handle is rigidly joined to the fist and can twist with it through only two right angles and bend with it through only one right angle relatively to the upper arm and forearm respectively. But the twisting and bending movements of the mechanical part of the fist can be much magnified by means of the eyes and links of

the chain; and the head can twist through several right angles and bend, or swing, round the arm through more than a right angle.

The handle is too long to be a mechanical reproduction of the forearm only; and probably is a mechanical reproduction of the whole arm; and it would seem the weapon requires to be wielded with the forearm and upper arm acting together.

7. *North American Indian Club* (*Figure 14*).

This club is made of wood. The spherical ball is held by the top of the handle in a manner somewhat resembling the manner in which a ball might be held in a partly clenched fist. This suggests that the top of the handle forms part of the head and is a transferred counterpart of the hand. The maker has apparently seen the ball as if in the mouth of an animal, and has made certain distortions to increase this effect.

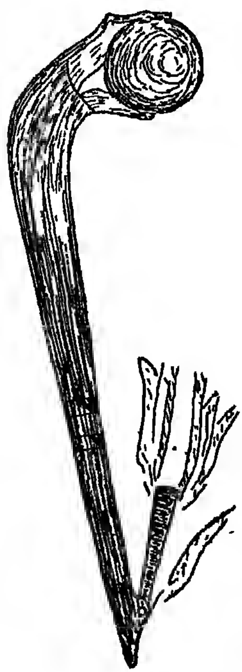


FIG. 14.
NORTH AMERICAN INDIAN CLUB
By permission of the Bristol Museum and Art Gallery;
(Goldwyer Collection).

The handle, from its length, must correspond to the whole arm. It increases in girth, as is usual with the handle of a club, from the grip to the head; and is therefore a reversed extension of the wielding arm which increases in girth, very irregularly, from the wrist to the shoulder. The handle is enlarged below the grip, and the enlarged part is an untransferred part of the fist or hand. Its lower end is pierced with a hole from which rudimentary wrist fastenings emerge. These are formed by a piece of leather with feathers attached to it. The leather originally was perhaps a thong to surround the wrist.

The club would need to be directed so that the ball hit the opponent, but perhaps could be used so that the part of the head behind the ball, which remotely resembles the back of a fist, could hit the opponent, and the type of blow would then correspond to one given by the back of a fist. If a blow were thus given by the top of the handle, both the back of the fist at the grip and the back of the fist at the opposite end of the handle, it can be noticed, would simultaneously be directed at the opponent, and the part of the back of the mechanical fist at the top of the club would imitate the movement of the part of the back of the human fist lower down, in accordance with Rule 4.

More facts about this club, and also about the other clubs discussed in this chapter, will become known when clubs are studied again, in Part II, with reference to the reproductive machinery of the body. It will then be seen that the head of this club probably corresponds to the skull and the part below the grip corresponds to the sacrum. The reason why the maker has seen the ball as if in the mouth or skull of an animal will then perhaps receive an explanation.

8. *Eskimo Adze* (*Figure 15*).

This is a tool and not a weapon, but the principles of tools are similar to those of weapons.

The handle and head are of bone. The point is of iron. The head is laced to the handle by thongs, and there is a thong binding round the grip, with a loop for the wrist.

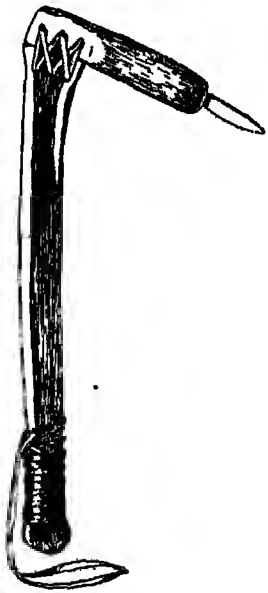


FIG. 15.
ESKIMO ADZE
British Museum Handbook

If a gardener wishes to make a shallow trench in loose soil, and has no tool handy, he will sometimes dig it with his

hand. The hand can quickly be formed into an adze type of tool, say by bending the two top joints of the fingers until they are about at right angles to the hand, or if a deeper trench is to be scratched, by bending the three joints until the fingers are at right angles to the palm. Loose soil can then be drawn towards the gardener, and a trench can be made.

An adze, like any weapon, tool, instrument, or other mechanical contrivance, can only extend actions of its wielder; and therefore each part of the adze must have its human counterpart. The handle acts as an extension for the wielding arm. The head is perhaps an extension of the part of the hand bent at right angles to the rest of the hand in a manner suggested above. The iron projection is a mechanical reproduction of one finger, or of a device made by several fingers together, or it is perhaps a mechanical extension of a finger nail or finger nails.

Part of the hand of the wielder of the adze is not bent at right angles to the rest of the hand. But in a developed weapon or tool, a mechanical part can release its human counterpart from the need for directly taking the shape of the part, as suggested by Rule 5. However the above suggestion of the derivation of the head of this adze should not be regarded as necessarily correct. but as a possible solution only.

The fastenings holding the head to the handle appear to be made from a thong; and correspond to fastenings which join the hand and arm. They are in a transferred position.

The grip is surrounded by binding in a very irregular spiral; and the grooves between the turns form a crude and irregular type of rifling, into which the hand and fingers press. This rifling is reproduced on the skin of the hand and fingers as they grasp the grip. The loop corresponds to fastenings connecting the hand and arm. Its purpose is to surround the wrist loosely, to help to hold the adze to the hand.

The materials of the handle and head, since these are of bone, correspond fairly closely to those of the bones of the wielding arm and hand. The materials of the fastenings,

since they are of leather or sinew, correspond fairly closely to those of the materials which hold the hand to the arm The iron point, or pick, does not correspond closely in materials to its human counterpart

9 *Wooden Club from Fiji (Figure 16).*

Apparently entirely of wood, except for the bindings. It is decorated with stars, moons, and similar objects.

The club, it is evident, must be wielded with both hands, and therefore the handle is an extension for both arms, and the head an extension for both hands. The head is not of the ball type; and cannot be a mechanical counterpart of the fists. It has something of the appearance of an open hand with fingers closed. Two different types of blows could be given, one a hit or smack with the flat surface, the other a cut or slash with an edge. A thrust could also be given with the point. These types of blows and thrusts correspond to those that could be given by the open hand, the effects when the mechanical extensions formed by the head are used being of course greatly magnified, for not only does the harder and sharper head allow harder and sharper blows to be given, but the leverage given by use of the long handle helps to magnify the effects of the blows or cuts.

FIG. 16. WOODEN CLUB, FIJI *British Museum Handbook*

There is a slight rim below the grip, which is an untransferred part of the hands. There are fairly regular bindings at intervals round the handle, and grooves are formed between the turns of the cords of the bindings, in which the skin and flesh sink when the handle is grasped; and mechanical riflings and human riflings then tend to fit into each other.

The club is decorated, and the decorations correspond to those often made on a wielder's arms or other parts of the body, like tattoo decorations. Decorating a club does not make it a more effective weapon any more than tattooing the body makes the human offensive machine a better

machine, but tattooing or decorating the body or the weapon will sometimes frighten an opponent.

10 *Boomerang* (*Figure 17*).

Some types of boomerangs are used simply as clubs, other types are thrown.

The weapon somewhat resembles an arm bent at the elbow, but it has no head and the fist is not reproduced by the weapon. It probably corresponds to the human weapon formed by the bent arm, such as is used, for example, when

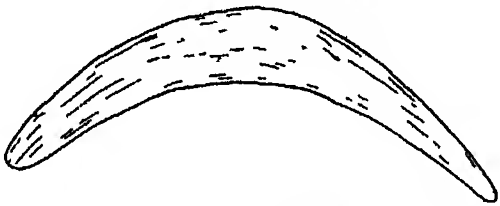


FIG. 17 BOOMERANG

a person "elbows his way" through a crowd, using only his arms but not his hands or fists. The elbow of the weapon is very pronounced. The grip is often chequered with lines cut on the surface.

11. *Waddy* (*Figure 18*).

This is a type of club, but is used mainly for thrusting. The head seems to be formed by a swelling about two thirds of the way up the weapon. This swelling is probably not an artificial reproduction of the fist; and the weapon perhaps

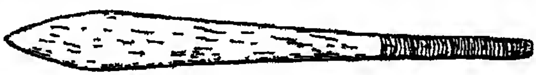


FIG 18. WADDY

corresponds to the human weapon that might be formed by an arm with the fingers outstretched and brought to a point with the palm folded.

12. *The Indian Club* (*Figure 19*).

The club is not a weapon, but is used in gymnastic exercises. The weight varies from about three to five pounds.

Some authorities recommend a three pound club for a woman, and a five pound club for a man. The length of the club is about the length of the forearm; but its girth and weight exceed the weight and girth of the forearm.

It seems that by juggling with the club it can be made to correspond at one moment to the forearm, and at another moment to the whole arm. In order to make these changes, advantage is taken of centrifugal force. The club is wielded with circular movements round the head or body; and at certain moments the weight of the club is hardly felt by the wielder's arm, and the club can then be wielded almost entirely by the forearm in a small circle. As the weight begins to tell, the club can be made to execute a wide circle with the whole arm in one line, and the club then acts as an extension for the whole arm. The rapidity and grace with which the club can be made to pass from the state of forming an extension for the forearm only to the state in which it forms an extension for the whole arm makes Indian club exercises very pleasant both to perform and watch.

FIG. 19. INDIAN CLUB

Chapter 16

THE SPEAR

THE human prototype of the spear with a leaf shaped blade can be seen if a hand and arm are stretched out, with the hand open and fingers closed. The arm then corresponds to the spear's shaft, the hand to the blade, and the point of the middle finger to the point of the blade. The human prototype of a double handed spear shaft can be obtained by stretching out both arms in opposite directions so that they are in line.

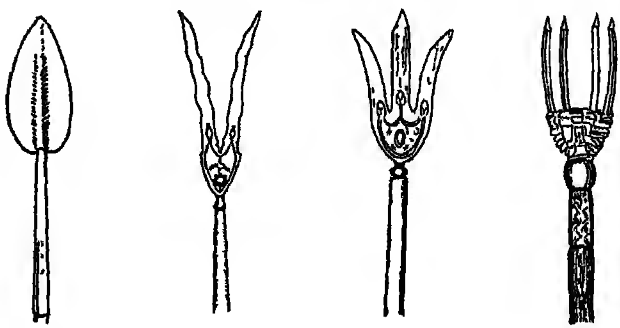
The weapon formed by the open hand with closed fingers has little penetrating power, and it is seldom used as a weapon, but mechanization of the weapon allows its power to be greatly increased. Mechanization of a human weapon nearly always allows its piercing or cutting or slashing or hitting powers to be magnified, often to a very great degree. The fingers used as claws have little clawing powers but, as has been shown, by mechanizing them by means of a baghnak their penetrating and clawing powers can be greatly increased. Similarly, although the knuckles of the bare fist have little penetrating or cutting powers, when they are mechanized by means, say, of a knuckleduster with sharp points, these powers are considerably increased. By mechanizing the fist and wielding arm by means of a club, a much harder and heavier blow can be given than can be given by the bare fist. By transferring a mechanical copy of a finger to the head of a club, in the form of a spike, the penetrating power of the finger can be greatly increased. Makers of tools have discovered that by use of a hammer, which is a type of club, a hard and heavy blow can be given by the artificial extension of the fist. By means of a blacksmith's sledge hammer, which is a type of club corresponding to both fists and arms, as is evident from the fact that it is wielded with both fists and arms, the smith can beat heated

iron into shapes he desires, a feat he would not be able to perform with unmechanized or bare fists. The art of the makers of weapons and tools has indeed been exercised to the utmost from the earliest times to discover methods of magnifying the hitting and piercing and cutting and other powers of the human body. Considerable progress was made by early man in extending and magnifying the hitting, thrusting, and cutting powers of the body, by the use of wooden clubs, pointed sticks, and edged sticks. More progress was made by using stone clubs and flint tools and flint weapons. But it was the use of metals and especially of iron and steel, that opened up ways of extending and magnifying these powers to very great degrees.

It is apparently to the weapon formed by the open hand and used for thrusting, with its many variations such as may be obtained by opening some or all of the fingers, that most types of spear heads correspond.

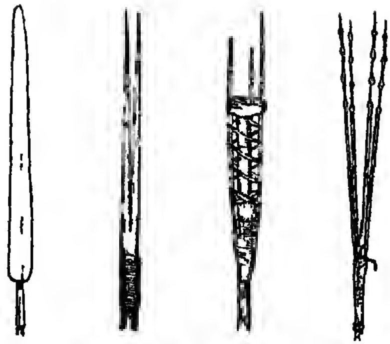
In *Figure 20* (*i*), the spear head is leaf shaped, and has some resemblance to an open hand with closed fingers. The spear head in *Figure 20* (*v*), is a variation of this type, and is distorted so that resemblance to a human hand is more remote.

FIG. 20. SPEAR-HEADS



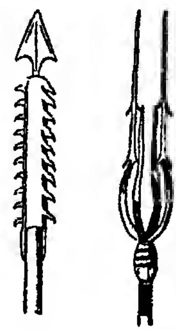
(i) (ii) (iii) (iv)

(i) Masai, *British Museum Handbook*
(ii) Bident, *Warrington Municipal Museum*
(iii) Trident, *Warrington Municipal Museum*
(iv) Four-pronged Dyak fishing spear, *J. G. Wood*



(v) (vi) (vii) (viii)

(v) Masai, *British Museum Handbook*
(vi) Double-headed javelin, Duke of York's Island, *J. Skelton*
(vii) Three-pronged spear, Lower Murray River, Australia, *J. G Wood*
(viii) Four-pronged Fiji spear, *British Museum Handbook*



(ix) (x)

(ix) Belgian Congo, *British Museum Handbook*
(x) Bissagos Islands, *British Museum Handbook*

In *Figures 20* (*ii*), (*iii*) and (*iv*), the fingers of the spear head are open, and branch from a broad part which fairly evidently corresponds to the palm of the hand. *Figure 20* (*iv*), which shows a fishing spear, has four fingers with devices at their ends somewhat resembling finger nails.

The heads of many spears are greatly distorted. Advantages for special purposes can be obtained by particular distortions; but no single distorted type is widely used; and the leaf shaped head or an elongated variety of it seems to be the type most widely used; and thus although the ingenuity of makers of spears has been exercised from the earliest times to discover ways of further mechanizing the thrusting hand or thrusting fingers device, the most widely used types of spear heads still reveal certain resemblances in shapes to the shapes of the human prototypes from which they have been derived.

Many war spears have barbed heads, and fishing spears very often are barbed. The barb is not an offensive device nor does it form part of the offensive machinery. It is a holding device by means of which an opponent or creature can be held after being hit; and corresponds to the device formed by a bent finger, as for example when a finger is bent round a hook or rope to draw it towards one or to hold it to one. The human prototype of the barb can be distinctly seen if the reader bends his forefinger at the middle joint, or fore-knuckle.

The recognition of the human prototype of the barb at once reveals that the fist is barbed, with at least fourteen prominent barbs. Four prominent barbs are formed at the four middle knuckles of the fingers, and four others at the four main knuckles, where the back of the hand and fingers meet. The points of the barbs formed by the middle knuckles are probably those most often directed against an opponent. They do not penetrate deeply, but may lacerate the opponent. The barbs are holding devices only when the fingers are used to grasp the opponent and hold him. Four more barbs are formed by the top knuckles of the fingers, but these are nearly hidden in the fist. Two barbs are formed by the thumb, one at each knuckle. The reader will easily notice the modifications in the forms of the human barbs when the hand forms claws or wields a caestus, baghnak, or other mechanical weapon; and will realize that every weapon formed by or with the hand or held by the hand is necessarily

and automatically barbed with at least fourteen prominent barbs. If a weapon is held by both hands, it is then provided with at least twenty-eight barbs.

Weapons like the pike and halberd, *Figure 21,* and quarter staff are varieties of the thrusting spear, or can be used as varieties of it. These weapons are double handed weapons, with long shafts or handles which are held with one hand higher up the shaft than the other. The shaft forms a rigid extension for both arms, as is evident from the length of the shaft and from its being wielded by both arms. The extensions of the arms are not placed side by side and combined to form a thick short staff of about the length of one arm, but are placed end to end to form a single slender extension; and often there is nothing to show where one extension begins and the other ends. Usually the shaft is approximately cylindrical in shape. None of the flexible or soft parts of the wielding arms are mechanized and given extensions by means of the shaft of a pike, halberd, or quarter staff. The shafts of thrusting weapons of the spear class vary little in form; and it does not seem possible with advantage to distort the mechanical extensions of the wielding arms to any great degree except in length.

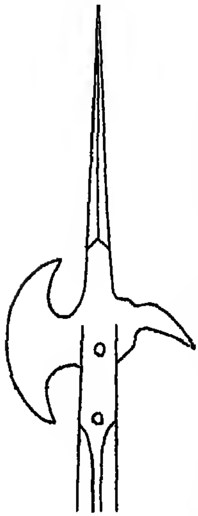


FIG. 21.
HALBERD HEAD
Wallace Collection
(From a photograph)

The head of a spear may be of one piece with the shaft; and the fastenings joining the head and handle are then formed simply by the materials of the part where the head and handle meet. A spear formed by a pointed stick has no defined head; and the part forming the head is joined to the handle by the wood which is continuous from handle to head.

The head often has a socket into which the shaft is fitted. Conversely often the head fits into the shaft. The head

sometimes has a tang, or metal spike, which fits into a socket in the shaft; but conversely sometimes the shaft ends in a tang which then fits into a socket in the head. The socket is thus sometimes in the head, and sometimes in the shaft, and similarly the tang is sometimes on the shaft and sometimes on the head. A joint formed by a tang on a head and socket in a shaft is a similar but opposite contrivance to a joint formed by a tang on the shaft and socket in the head; and a study of these similar but opposite contrivances helps to show how devices can be reversed and how devices can be transferred. Thus the socket can be transferred from the head to the shaft or from the shaft to the head, and similarly the tang can be transferred from the head to the shaft or conversely; because head and shaft are in contact (Rule 7). Transferring the devices has of course the effect of reversing the form of the contrivance (Rule 11).

A shaft fits into a socket in the head of a spear in much the same way as a finger fits into the finger of a glove. The tang of a shaft is indeed a mechanical extension of a thrusting finger transferred from the wielder's hands to the opposite end of the shaft; but the tang of the shaft is not directly used against the opponent. This device appears again as the point of the spear's head, the tang device of the shaft being transferred to the opposite end of the head. No doubt, if the head were dislodged, the tang or end of the shaft could be used directly against the opponent; but by transferring the mechanical tang device to the head the more effective and of course modified form of the device, formed by the point of the spear's head, can be used. Thus, the point of a spear head originates as the human thrusting finger device, which is transferred as a mechanical device to the end of the shaft opposite the hands, appearing often as the tang on the shaft or conversely as the tang on the head, and is then again transferred in a modified and further distorted mechanical form to the opposite end of the spear's head, appearing lastly as the metal point of the head.

Since the head of a spear corresponds to the hand and the shaft corresponds to the arm or arms, the fastenings which

hold the head of the spear to its shaft must correspond to the human fastenings which join the hand and arm, that is must correspond to the wrist fastenings. The mechanical fastenings, however, are not near the wrist but are in a transferred position, being transferred to the end of the shaft opposite the hand or hands (Rule 8). A spear head is rigidly joined to its shaft, and the head and shaft cannot move relatively to each other. Hence the mechanical joint can reproduce only features of the set wrist, that is can reproduce only features of the fastenings which are formed by the wrist when the hand is held rigidly by the wrist without movement of the wrist. But flexible joints can be seen in the fastenings which connect the heads and shafts of harpoons, which are types of spears, if the head is made so that it can be detached from the shaft but be still connected to it by a cord or cords.

It might be thought that in such primitive types of weapons as spears and harpoons correspondence between mechanical and human joint fastenings could not be observed, or could be observed only with great difficulty. To some extent this is true; but often correspondence is clearly evident, and in some cases correspondence of mechanical and human parts or devices is astonishingly close, as will now be shown.

The head of a Kaffir's assagai usually has a tang which fits into the shaft, or the shaft may have a tang which fits into the head. The Kaffir further secures the head to the shaft by binding the joint with a strip of hide. The hide thong is wound round the joint while still wet, and as it dries it contracts and "forms a band nearly as strong as if made of iron."[1] This thong binding around what might be called the "wrist" of the weapon has some similarities to the thong binding which surrounds the wrist of the wielder of a caestus, and also to the tape which surrounds the wrist and glove of a modern boxer, and is a type of the caestus wrist thong or boxing tape; but the caestus thong or boxing tape is not in a transferred position but lies around the wielder's wrist. The assagai binding is not near the wielder's wrist but, as stated

[1] The Rev. J. G. Wood, M.A., F.L.S., etc., *The Natural History of Man.*

above, is transferred away from the wrist to the end of the shaft near the head. The assagai's thong binding perhaps has some correspondences to the sinews or other fastenings which join the hand to the arm, but correspondences are remote.

It was pointed out in the chapters on the caestus and boxing glove that the part of the glove of the caestus or part of the boxing glove which surrounds the wrist is a mechanical copy or extension of the skin of the wrist. The African sometimes very clearly reproduces certain features of the skin of the wrist in the fastenings which join the head and shaft of his assagai. The joint in some specimens is secured by a piece of the tail of an animal, say about four inches of the tail of a calf, drawn on like a stocking.[2] As the skin tube dries, it contracts, and covers the joint in much the same way as the skin of the wielder's wrist covers the human joint of the hand and arm. Also, usually, the hair is left on the skin tube; and the hairs on the tube then reproduce in artificial and distorted forms the hairs on the wielder's wrist.

A harpoon's head may be lightly attached to its shaft by a cord or cords, so that when a creature is struck, the head can remain in its body and the shaft can float away but still be connected to the creature by the cord or cords fastened to the head. The position of the creature under water can then be known. Also, the shaft, to which an inflated bladder is sometimes fastened, acts as a float and prevents the creature swimming away easily or prevents it sinking. A long line is fastened to the shaft so that the creature after being struck can be held by the harpoon.

The cords holding the head of the harpoon to its shaft must be mechanical reproductions of the flexible fastenings, such as sinews, which connect the wielder's hand and arm. This is evident from correspondences of positions and functions of human and mechanical parts. But the mechanical cords are greatly distorted, especially in length, compared with their human counterparts.

[2] Richard F. Burton, *The Lake Regions of Central Africa;* The Rev. J. G. Wood, M.A., F.L.S., etc., *The Natural History of Man.*

By distorting the cords of the arms the harpooner obtains certain advantages. Thus, for example, by distorting the mechanical extensions of the cords of his arms, he can remain at a considerable distance from the creature he is holding, and can hold it by the help of the flexible extensions provided by the rope fastened to the shaft. But distortion of a part or device of a weapon, if the weapon is to be of service, cannot be according to the whims of its maker. The harpooner has discovered, by a long process of trial and error, some of the ways in which parts of a harpoon can be distorted with advantages for his purposes. Distortion also can probably be made only in accordance with laws or rules, which however are not yet known. The Rules given in this work are not sufficient to account for the ways in which weapons can be distorted. But probably when a study of weapons is made by others than the author by means of the human prototype theory, further laws or rules describing the ways in which weapons originate and develop will become known, and perhaps the ways distortion can take place and the limits to which it can be carried will become known. In the meanwhile the Rules given will provide means of knowing, broadly, how weapons originate and develop, and more important still how new weapons will originate and develop.

The head of a harpoon is sometimes fastened to its shaft by means of a cord from the base of the head, but this method of fastening the cord allows the head to be pulled out of a creature too easily. Therefore in many types of harpoons, the cord is fastened, not to the base but to the side of the head, so that the pull of the cord on the head does not tend to pull out the head but rather tends to prevent it being pulled out. The pull on the head when the cord is fastened to its base is along its axis, but when the cord is fastened to its side is at right angles to the axis. The change in place of attachment therefore results in the pull being turned through a right angle, in accordance with Rule 10.

Characteristics of the fastenings which allow the hand and arm to be rigidly joined are therefore reproduced in

rudimentary and distorted forms by the fastenings which join the heads and shafts of spears; and characteristics of the fastenings which allow the hand and arm to be flexibly joined are reproduced in rudimentary and distorted forms by the fastenings which join the heads and shafts of the harpoons.

The head of a spear is sometimes fastened to its shaft by rivets, or rivets form part of the fastenings. It is then fastened somewhat after the manner in which a surgeon fastens a broken limb when he rivets the parts together say by silver nails. The methods used by a surgeon are far removed from those used by nature; but sometimes show correspondences to methods by which makers of weapons fasten the heads of halberds, pikes, and similar types of weapons to their shafts (Cp. *Figure 21*).

A halberd, whose head is provided with an axe and a point and a beak, is not one weapon, but is really three weapons, and only one of the weapons can be used at a time, *Figure 21.* The halberd can be used as a thrusting spear or as a battle axe or as a kind of pick axe. When the spike is being thrust at an opponent, the axe and beak are out of action, and similarly when either the axe or beak is being used, the other two devices of the head are out of action. When one weapon is being used, the other two devices of the head are usually hindrances to its effectiveness. Thus, if a thrust is being made with the spike, the axe and beak because of their weights tend to make the thrust more difficult. A dual purpose or many purpose weapon is nearly always less satisfactory in use than a single purpose weapon. The human body it can be noticed cannot form more than one type of offensive machine at once. Thus an opponent cannot be hit with the fist and be torn with the claws at the same time; and the fist and the claws must be separately formed and used.

A barrel is formed by the hands and fingers as they close round the shaft of a pike, halberd, quarter staff, or double handed thrusting spear, *Figure 22*. Parts of a cylindrical barrel are formed if the shaft is cylindrical; for the skin and

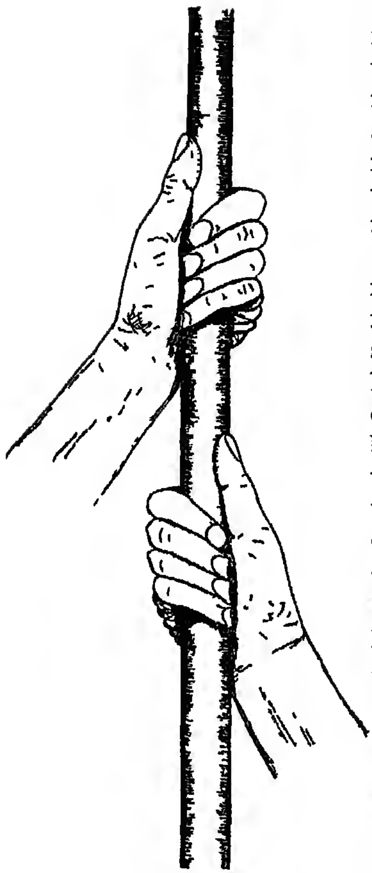


FIG. 22.
THE HANDS FORMING A BARREL

flesh of the hands and fingers become deformed through pressure as the shaft is grasped, and automatically the form of the shaft is impressed on the insides of the hands and fingers where they are in contact with it. The human barrel is in two main parts, one part being formed by the right hand and the other by the left hand. Usually the two parts of the barrel are separated by some distance, the distance depending on the way the shaft is held. The axis of the human barrel coincides with the axis of the shaft; and the axis of one part of the human barrel is in exactly the same line as the axis of the other part.

When it is seen that a barrel is formed by the two hands for a spear shaft, it can be seen that the hands form a barrel when the fists are being wielded; and that the barrel of the fist machine like that of the thrusting spear machine is in two parts. One part is formed by the hollow of the left fist, and the other by the hollow of the right fist.

The relationships between the barrels of the fist machine and thrusting spear machine can be at once understood from a simple experiment:—

Hold a pencil in each fist, and adopt an attitude of the

wielder of the fists with, say, the left fist forward. The pencils will point upwards and will be parallel. Now turn the fists until the pencils are in the same straight line. Without changing the positions of the fists, replace the two pencils by a cane or stick. The hands will now be holding the shaft of a spear; and the attitude will be an attitude of the wielder of a thrusting spear.

Placing pencils in the fists reveals the positions and directions of the hollows or barrels of the fists, and shows the directions of the axes of the barrels. The fact that the fists have barrels and that the barrels have axes cannot be known from direct observations, but becomes evident when pencils are placed in them, or when they are turned through right angles and made to hold a spear shaft. When the cane or stick is placed in the hands it enlarges and fills the hollows or barrels of the fists, and causes the interiors of the two parts of the human barrel to be deformed to fairly regular cylindrical shapes. Since the hands are on the same cane or stick, the two human cylinders have the same axis, which is also the axis of the cane or stick; and the interiors of the cylinders coincide with the exterior surface of the cylindrical cane or stick where they are in contact with it.

The diameter of the barrel formed by the hands when holding a spear shaft depends on the diameter of the shaft, and is the same as that of the shaft. The hands have the remarkable property of being able quickly and automatically to form a barrel for a shaft of any diameter, provided the shaft is not too large to be held. Some mechanical barrels also have this property. For example, an amentum, or thong wound round the shaft of a spear, can fit a shaft of any diameter, and therefore the barrel formed by the thong cylinder can automatically adapt itself to suit the girth of the shaft. Somewhat similarly, the barrel formed by the sides of a sling pouch automatically diverge or approach each other to suit the size of the sling stone. A gun barrel has no powers of adapting itself to suit the diameter of the missile; but contrariwise can make the missile suit its own diameter. This happens when the lead bullet or the driving

band of the shell is forced into the rifling grooves. These facts will however be better understood later in the work.

A thrust from a spear is given along the axis of its shaft, and therefore also along the axis of its human barrel. A thrust or blow from the fists however is given at right angles to the barrels of the hands (Rule 10). It can be seen that a blow or thrust is always given in a direction either parallel or at right angles to the human barrel. Thus, a blow from a club is given at right angles to the handle, and therefore at right angles to the barrel formed by the hand or hands at the grip. A sword thrust is given in a direction along the axis of the barrel of the hand; but at right angles to it when a katar type of sword is wielded and the hilt is at right angles to the blade. A cut or slash from a sword is given at right angles to the axis of the human barrel. A blow or thrust from a rifle is given in a direction parallel to the line joining the hands. And so on.

Although the surface of the shaft of a spear may be smooth, the surface of the interior of the human barrel will not be smooth. However great a pressure is exerted by the hands, parts of a cylinder will not be exactly reproduced on the skin of the hands and fingers, because of the creases and lines on the palms and insides of the fingers, and because also of the grooves between the fingers, formed by the three spaces between the four fingers of each hand. There is a multitude of creases and fine lines on the palm and insides of the fingers. No two persons have the same pattern of creases and fine lines, and the creases and fine lines on the inner surface of the human barrel are different when one person grasps the shaft and when another person grasps it.

The three grooves between the fingers of a hand are approximately straight and parallel when the hand is open and the fingers closed; but they tend to become spirals, or screw-like threads when the hand grasps a spear shaft. Those formed by the left hand when it is the forward hand are right handed threads; those formed by the right hand are left handed threads; and the three threads of the left hand

are approximately at right angles to those of the right hand. If the threads of the right hand were continued round the shaft, they would not therefore meet and coincide with those of the left hand, but would cut them at right angles approximately. The threads are very irregular, and not so machine-like as the threads of screws or the riflings of gun barrels.

Three other spirals are also formed by each of the hands on the inner surface of the barrel. These are formed by the creases at the insides of the finger joints. When the hand is open, twelve short and separate creases can be seen at the insides of the finger joints, four being at the insides of the top joints, four at the insides of the middle joints, and four where the fingers meet the palm. The creases are parallel, and at right angles to the fingers. As the hand becomes clenched the four top creases tend to form one continuous crease, the four middle creases similarly tend to form a continuous crease, and the four lowest creases tend to form a continuous crease, each crease crossing the fingers approximately at right angles to them. When a spear shaft or other cylindrical shaft is grasped these three creases tend to become spirals. So on the interior of the human barrel other sets of spiral grooves, or riflings, are formed by the creases at the insides of the finger joints, which are approximately at right angles to those formed by the grooves, or spaces, between the fingers.

The interior surfaces of the human barrel of a spear shaft, pike shaft, or halberd shaft, are therefore rifled. In anticipation of later results, it may be stated that the barrel formed by the hands is a prototype of the gun barrel and the human riflings are prototypes or original forms of the riflings on the interiors of rifle, machine gun, howitzer, naval gun, and other gun barrels. The human originals must not be supposed to be inferior to the mechanical riflings on the barrels of rifles and other fire-arms, because they seem so irregular. The human riflings are extremely complex; and the above study of them reveals only a very few of their properties and characteristics. The mechanical riflings on the interiors of

fire arms reproduce only very crudely and in a most primitive way some of the properties of the human riflings.

Attempts at reproducing human devices in mechanical forms nearly always result in the production of devices much more regularly formed than their human counterparts, and usually of some simple geometrical forms. But the production of a device of a regular and geometrical form does not mean that the mechanical device is in any way superior to the apparently less regularly formed human device. This can at once be realized by considering say the development of artificial limbs. Until recent times a wooden leg was usually merely a cylinder somewhat resembling a broom handle. It was much more regular and geometrical in shape than the human leg it was meant to replace. From a mathematical point of view it could be said to be superior to a human leg, which is very irregular in form and of no known geometrical shape; but the wearer of such a contrivance would undoubtedly say it was a very crude and elementary reproduction of the leg. It can be noticed that as artificial legs have been improved they have tended to become less mathematical in shape and correspondingly more useful to the wearer. It must not be imagined that mechanical riflings are superior to those formed by the hands when they grasp a spear shaft because the mechanical riflings are more regular and geometrical in shape. The need to make parts of weapons in regular and geometrical shapes is an indication of the lack of ability of the makers. Makers of weapons must make parts of weapons in simple and regular shapes, because they know so few of the secrets of the offensive machine and cannot therefore reproduce any of its parts with fidelity. Indeed, until the publication of this work, makers of weapons apparently did not know that parts of weapons are extensions of parts of the wielder's body, and hitherto have worked blindly, developing weapons by a process of trial and error.

It may also here be stated that the multitude of creases on the surface of the palm and insides of the fingers do not form rifling devices, and are not mechanized in weapons as

riflings. One of their purposes is to help the hand to grip the shaft, and they act somewhat like the treads on the wheels of vehicles to prevent slipping. They are mechanized on some weapons as the chequering, or criss-cross markings lightly cut on the small of the stock and other parts to help the hand or hands to obtain a good grip, *Figure 57*. Chequering devices will be studied later.

A pike shaft or halberd shaft has no movement relative to its human barrel while the weapon is being wielded, and the shaft and barrel move together always. The shafts of most double handed spears similarly do not move relatively to the barrel; but certain types of spears are darted through the hands; and the shaft moves through the barrel, in somewhat the same way as a bullet moves through a gun barrel.

According to Wilkinson, the ancient Egyptians sometimes darted the spear through the hands, but without letting it pass from the hands. The shaft was darted through the hands, "till stopped by the blow or by the fingers suddenly closing on a band of metal at the end." Wilkinson also says a spear is sometimes darted by the modern Nubians and Ababdeh in this way.[3] On some spears the place of a metal band is taken by a knob at the butt.

The hands remain at the same places on the halberd, quarter staff, and spear shaft, when the grip has been made, and do not move relatively to each other during the wielding movements. Hence the length of the barrel is constant. But when a spear is darted the length of the barrel varies, because the hands move relatively to each other during the darting movements. Hence the darting spear machine has an extensible barrel, or barrel whose length changes as the weapon is being wielded.

Many other types of the offensive machine have extensible barrels. The fist machine, for example, has an extensible barrel, because the distance between the hollows or barrels of the fists varies as the fists are being wielded. The length of the barrel is least when the fists are close together, say as

[3] Sir J. Gardner Wilkinson, D.C.L., F.R.S., F.R.G.S., *The Manners and Customs of the Ancient Egyptians.*

the rear fist is being brought forward and the front fist is being brought back; and is greatest probably when the rear fist is about to be brought forward to deliver the blow or at the moment the opponent is hit, for then the fists are farthest apart.

If the length of the barrel of the one handed club machine is regarded as the distance between the human fists, the maximum length of the barrel is probably not much different from that of the fist machine; but perhaps the length must be measured from the part of the barrel formed by the hollow of the left fist to the part formed by the head of the club, which is an artificial copy of the right fist at the grip; and the length of the handle must be added to the distance between the human fists to obtain the maximum length of the barrel for most types of blows. A two handed club machine has not an extensible barrel, because both fists are on the handle, and the distance between them does not change, nor does the distance between the human fists and the head of the club change.

The hand and fingers, besides forming a barrel for the shaft of a spear, form fastenings to connect the weapon to the body. These fastenings, like the riflings and indeed all human devices, are extremely complex. They are not mechanized and therefore it is impossible to see how they are formed or to discover all their parts and devices, or to see them separate from the barrel and rifling and chequering and other devices; but a few general remarks about them can be made.

The fingers curl round and surround or partly surround the shaft, and form clasps to hold the shaft to the arms. Each finger forms a separate clasp. The thumbs when placed along the shaft press on it and press it against the finger clasps. If the thumbs curl round the shaft they also form clasps which may meet and lie over the ends of the fingers. The forms of the clasps depend to a great extent on the girth of the shaft and the shape of its section. The clasps are automatically and quickly formed by the hands as they grasp the shaft. When a spear is darted the clasps

are slightly loosened. As a thrust is being given they are tightened.

Many spear shafts have smooth surfaces, and have no special devices fastened to them. But the human barrel is often provided with an artificial or mechanical extension, formed usually by covering the grip with leather, skin, velvet, or other similar material. The assagai, for example, sometimes has a leather covering round its grip, which acts as a mechanical counterpart for the human barrel. When the shaft of a spear is approximately cylindrical, the mechanical tube or barrel formed by the leather, skin, or velvet, is also approximately cylindrical, since it necessarily takes the form of the surface of the shaft. When the hand makes its grip, the shaft is therefore provided with two barrels, a mechanical barrel to enclose the shaft being formed by the covering placed round the shaft, and a human barrel being formed by the hand to enclose the mechanical barrel and the shaft. A close fit of the human barrel, mechanical barrel, and shaft is ensured, because of the pressure of the hand on the grip.

The shaft of an African spear is sometimes plated with zinc or tin,[4] and the zinc or tin tube then has some resemblances to a gun barrel, in materials, shape, and size; but the shaft does not move through the metal barrel as a bullet or shell moves through a gun barrel.

The complete barrel for the shaft is formed by the hand and tube of skin, leather, velvet, zinc, tin, or other material; and the artificial part of the barrel is complementary to the human part. The human barrel automatically conforms to the shape of the artificial part; but if the tube is of soft material like skin, leather, or velvet, the mechanical part of the barrel may be deformed somewhat to the shape of the human barrel.

The tube forms a lining for the human barrel and since it lies next to the skin is evidently an artificial extension of the skin of the interior of the human barrel (Rules 3 and 7). That this is so is also shown by correspondences of materials

4 Richard F. Burton. *The Lake Regions of Central Africa.*

when the tube is made of skin or leather (Rule 1), by correspondences of shapes, because the interior of the human barrel becomes approximately cylindrical when placed on the cylindrical tube (Rule 1); and because the skin and tube move together at all times and cannot have independent movements (Rule 4). The materials of the interior of the human barrel and of the tube correspond fairly closely when the tube is made of skin, rather less closely when it is made of leather, much less closely when it is made of velvet, and only remotely when it is made of metal.

If the bark is left on a spear shaft, the shaft is automatically provided with a very close fitting barrel for most of its length. The bark is, of course, the skin of the wood, and by leaving it on the wood, the human skin is easily provided with an artificial and suitable mechanical extension. This circumstance might be overlooked, but it is necessary to notice it, because often the human skin is provided with an artificial extension by the simple expedient of leaving the bark on the wood which forms part of a weapon. Sometimes bark is purposely placed on the surface of a part to provide an artificial counterpart for the human skin. Thus, as will be shown later, the bark forms a mechanical counterpart for the skin of the wielder's arms when it is left on a self bow; and it forms a mechanical counterpart when it is placed on the surface of a composite bow. A part of a weapon, it should also be noticed, is given a type of artificial or mechanical skin when it is covered with varnish or lacquer or paint. Composite bows nearly always have an artificial skin of bark, skin, varnish, lacquer, or other material that copies the skin of the arms. When the bark is scraped off the shaft of a spear and is replaced in part by a tube of skin or other material, the natural barrel is replaced by an artificial barrel. An artificial barrel is supplied usually in order to obtain some advantages for special purposes.

A few types of spears have hollow shafts. A hollow tilting lance belonging to the Duke of Suffolk shown in London in 1598 to the German traveller Hentzner was 14 ft. 4 ins. long with a girth at its thickest part of 27½ inches,

but weighed only 20 lbs., and must therefore have had a large hollow.[5] A broken lance in the Tower of London, of about the same period, is 12½ feet long and weighs only 10 lbs., and has a hollow groove some two inches in diameter extending to about 1½ ft. from the point.[5] Large hollow spears, called bourdonasses, were used at the battle of Fornoue in 1495.[5] The hollow of the fists is filled by the wood of the shaft usually, but when a hollow spear is held, the hollow appears again within the barrel of the hands.

An artificial barrel is provided for a cricket bat or hockey stick when its handle is bound, as it usually is, with a length of cord wound spirally round it. The surface of this nearly cylindrical barrel is not smooth, but is very regularly and closely rifled, a continuous groove from one end of the handle to the other being formed between the turns of the cord. The pitch of the rifling, or number of turns the spiral groove makes in each inch of barrel, depends on the thickness of the cord, and can easily be measured or calculated. If the cord could be removed entire from the handle, it could be seen that the inner as well as the outer surface of the cord barrel was rifled.

The barrel for the cricket bat or hockey stick is not formed merely by the cord cylinder. The complete barrel is formed by the hands and by the cord cylinder together. The cord cylinder forms a kind of lining for the human barrel and becomes a mechanical extension for its inner surface. As they make their grips, the hands form a human barrel which takes the shape of the cord barrel. The human part of the barrel is in two parts, if the hands are at some distance apart, and it may therefore not be continuously formed. The mechanical part of the barrel is continuously formed if the binding is in one piece. The hands through pressure deform the skin and flesh to conform to the shape of the cord cylinder, and a close and good fit of the hands and bat or stick is ensured, and the body and bat or stick become firmly connected.

[5] Viscount Dillon, *The Encyclopaedia of Sport,* article Obsolete Sport.

The pressure of the hands causes the skin of the interior of the human barrel to receive impressions of the mechanical rifling formed by the spiralled cord. The skin sinks into the spiral groove, and the cord presses into the skin. The human barrel therefore becomes temporarily rifled with a simple type of mechanical rifling. It is however rifled also with its own human riflings. Ideally, the mechanical rifling should fit into the human riflings. Thus, the fingers should sink into the spiral groove, and the cord should fill the spaces between the fingers; but the spiral groove is much too narrow for the fingers to fit into, and the turns of the cord are too close to rise into the finger spaces. The mechanical rifling is but a very rudimentary and simple type of rifling, and cannot therefore match and fit the very irregular and complex human riflings. The human and mechanical riflings, however, are in contact when the hands make their grips; and the mechanical rifling is clearly a form of the human riflings and derived and transferred from them (Rules 1, 3, and 7).

Sometimes the cricket or hockey player places a rubber tube over the cord binding. Two artificial barrels are then provided for the handle; and the complete barrel is then in three main parts, a human and outer part being formed by the hands, a mechanical part by the rubber tube, and another mechanical part by the cord binding. The hands force the rubber against the cord cylinder; and the rubber is forced into the spiral groove which runs round the handle, and the turns of the cord press into the rubber. The rubber tube therefore becomes rifled on its outer and inner surfaces. The outer surface is rifled with the impressions of the riflings of the hands, and the inner surface with the simple mechanical rifling impressed from the cord cylinder.

Several sets of riflings are therefore formed on the various parts of the barrel of a cricket bat or hockey stick when a rubber tube is fitted over a cord binding. Human riflings are formed on the inner surface of the human barrel formed by the fingers. These are transferred in fairly accurate forms to the outer surface of the rubber tube with which the hands

are in contact (Rules 1, 3, and 7). If the rubber is thin or very soft, the pattern of the human riflings may also be transferred to the inner surface of the rubber tube, that is from the outer to the inner surface of the rubber barrel (Rule 8). The single spiralled groove on the cord cylinder is transferred to the inner surface of the rubber tube, as a result of the pressure of the hands (Rule 7). The outer surface of the cord cylinder itself is rifled by its own spiral groove, and its inner surface is also rifled with the same rifled groove, the outer and inner riflings being transferred copies of each other (Rule 8). If the cord is unwound from the handle, often rifled impressions of the cord can be seen on the handle, often in the wood itself, but often also in the bits of gum left sticking to the handle, when as is usual, gum is used to help to hold the cord binding in place.

The processes of transference of parts and devices of weapons have some analogies to the processes of transference of electrical charges. Thus, in the experiment with the apparatus known as "Faraday's butterfly net", an electrical charge can be transferred to either surface of the net at will. The net, which is made of linen gauze, is furnished with two silk threads to allow it to be pulled inside out in either direction. By pulling one silk thread, the charge can be at once transferred from one surface to the other, but always from the inner to the outer surface. Electrical actions can be transferred also from one end of a wire to the other, as for example when a telegraphic signal is transmitted or transferred along a wire. It will be shown later that an offensive action can be transmitted or transferred somewhat similarly along a rope or along the trajectory, from one end of the rope or trajectory to the other. The study of weapons however has not been sufficiently advanced by the author for him to be able to say if there is a fundamental connection between electrical and offensive phenomena, or if laws can be formulated to describe both types of phenomena.

Sometimes the grip or handle of a cricket bat, hockey stick, baseball bat, lawn tennis racket, or other implement used in games, is covered with a length of adhesive or

gummed tape. The tape then forms a type of artificial and cylindrical barrel; and grooves, usually of a very irregular pattern, are formed by the turns of the tape, and are types of riflings. If the tape is soft or sticky, the pattern of the human riflings of the hands may be transferred to the outer surface of the tape barrel (Rules 1, 3, and 7).

Types of mechanical barrels and riflings somewhat resembling those on cricket bats and hockey sticks whose handles are covered with cord and rubber, are occasionally found on spear shafts. For example, two German boar spears, of about 1600 A.D., in the Wallace Collection in London, have their hafts "plaited with leather thongs secured by round-headed nails, and partly bound with red velvet."[6] The velvet forms a barrel, approximately cylindrical in shape, over the plaited leather thongs; and riflings are formed by the grooves between the turns of the thongs. The riflings become transferred to the interior of the velvet barrel as the hands make their grips. The mechanical riflings impressed on the inside of the velvet barrel are not in contact with the fingers which are placed on the outer surface of the velvet. They are therefore in a transferred position, and are transferred from the outside to the inside of the mechanical barrel, that is from one side of the barrel to the other (Rule 8). They are very imperfect copies of the human riflings; but probably reproduce very distantly some of their characteristics. Similarly, when a rubber tube is placed over a cord binding on the handle of a cricket bat or hockey stick, the mechanical riflings formed by the spiral groove of the binding are transferred from the human barrel to the opposite side of the tube (Rule 8), as very imperfect and distorted reproductions or extensions of the human riflings.

A short stabbing assagai occasionally has an artificial extension for the barrel of the hand, formed by a piece of leather placed round the shaft just where the spear balances, with rudimentary extensions for the human riflings formed by turns of the wire-like hair of an elephant's tail placed at

[6] Wallace Collection Catalogue, *European Arms and Armour*, Nos. 347, 349.

each end of the mechanical barrel The hairs secure the ends of the bindings to the shaft, and are ornamental additions, but also are embryonic mechanical riflings Several wide rings of the same materials decorate the shaft of the weapon, "and all of them are like the well known "Turk's head" knot of the sailors"[7] According to Burton many African spears are "ornamented with twists of brass and copper wire." The wire bindings serve as ornaments, but rifling devices are formed by them, which have some resemblances to those formed by the cord binding on a cricket bat or hockey stick.

Rifling is sometimes formed by bindings placed spirally round the shaft of a weapon. An English bill of about 1515 in the Wallace Collection has its shaft bound with spirally twisted red and brown brocade, and riflings are formed by the turns of the brocade.[8]

When the maker of a spear type of weapon does not provide mechanical rifling devices, he sometimes represents them by painting a spiral or several spirals along the shaft. Thus a tilting lance in the Wallace Collection has its shaft "painted red with a spirally-curved band of white"[9] and another one has its shaft "painted with spirally-curved bands of red and white."[10] A pike also has its "haft painted with red and white bands spirally-twisted."[11] The pike's haft apparently somewhat resembles a barber's pole, which formerly "indicated the ribbon for bandaging the arm in bleeding."[12] The basin slung at the end of the pole indicated the basin to receive the patient's blood. The pole is evidently a type of arm, and therefore is related to the pike's shaft which it has been explained is a mechanical extension for the wielder's arms.

Straight grooves along the length of the shaft are found on many tilting lances, and as many as eight to twelve deep

[7] The Rev. J. G. Wood, M.A., F.L.S., etc., *The Natural History of Man*.
[8] Catalogue, No. 332.
[9] Catalogue, No. 330.
[10] Catalogue, No. 321.
[11] Catalogue, No. 357.
[12] *Encyclopaedia Britannica*, Article, Barber.

flutings or grooves may be provided. The lance mentioned above which belonged to the Duke of Suffolk has twelve deep flutings extending some 6½ feet towards the head. The grooves, although straight, are types of riflings, as can be understood from the fact that gun barrels before makers were able to twist the grooves to spin the missile often had straight grooves. Twisted grooves of guns have been developed from straight grooves which therefore are mechanical prototypes of twisted grooves.

The hand is not placed on the shaft of the tilting lance when in action, but round a special grip usually cylindrical in section and smooth; but at other times may be placed on the shaft. An illustration in Pluvinel's *Instruction du Roi* shows a knight in full armour with his hand on the fluted shaft of a tilting lance, the shaft having very deep flutings, apparently four in number.

Any shaft having a square, pentagonal, hexagonal, or octagonal section, is automatically provided with riflings; because each ridge impresses an angular groove in the skin and flesh of the hand as it holds the shaft. If the shaft has a square section, four grooves are impressed on the interior of the human barrel; if it has a pentagonal section, five grooves are impressed; and so on. For a handle of square section, the angle in the rifled groove is 90 degrees; for a handle of pentagonal section, 108 degrees; for one of hexagonal section, 120 degrees; and for one of octagonal section, 135 degrees.

It can now be seen that the rifling devices formed by the hands are reproduced by the bindings or other devices on the shafts of spears. The patterns of the human riflings are reproduced fairly closely sometimes, as when the grip is covered with a rubber or skin tube which is soft enough to receive the impressions of the human riflings as the hands make their grips. But the impressions on the rubber or skin tube disappear when the hands are removed. Permanent riflings which correspond less closely to their human prototypes are formed by the spiral groove between the turns of a cord binding, or by the irregular grooves in thong bindings.

Permanent riflings which correspond with much fidelity to the human riflings cannot be made on spear shafts, for the hands seldom make their grips more than once at exactly the same places; and the positions of the hands may change during the wielding movements. Also the pattern of the wielder's hands is not always available to the maker, and a pattern which suited the hands of one wielder would not suit those of another wielder. Also, the human riflings can be varied in forms and, except when soft materials are placed round the shaft, the mechanical devices cannot be made to possess the property of varying to correspond to the variations in the forms of the human riflings.

Furthermore, the bindings or patterns on the shafts or handles of weapons often reproduce the chequerings as well as the riflings of the hands. The skin of the hands is covered with a multitude of creases and fine lines. One of their purposes is to help the hand to obtain a good grip of any object being held; and they serve much the same purpose as the treads of rubber tyres in giving a good grip of a surface. Chequerings as well as riflings are, of course, reproduced on the rubber coverings of cricket bats and hockey sticks. The chequering and rifling devices are not often separately mechanized on elementary weapons like spears and clubs; and it is therefore usually very difficult to distinguish the two devices. Occasionally only the rifling devices are copied. Thus, obviously only the rifling devices are copied by the spiral band or line painted on the shaft of a tilting lance or pike, for the band or line has none of the criss-cross or irregular patterns characteristic of the human chequerings. Only the rifling devices also are copied in the single spiral groove that runs round the cord binding on a cricket bat or hockey stick handle. Possibly, only the chequering devices are reproduced by plaited bindings and by criss-cross cuts or markings on shafts or handles.

It is clear therefore that mechanical riflings on some shafts and handles correspond very closely and on others very remotely to their human prototypes. They vary from the

almost exactly reproduced inverted copies of the human riflings formed temporarily on rubber grips or semi-permanently on gum covered grips to the merely symbolical riflings formed by a spiral painted on a shaft. They range from the very irregular and complex forms reproduced on rubber tubes to the regular and simple form reproduced when the handle is covered with a single length of cord wound spirally round it. And they vary from forms which obviously reproduce human riflings to forms where resemblances cannot easily be seen.

Distortion no doubt is responsible in many cases for divergencies of the mechanical riflings from the forms of their human counterparts. But certain limits are imposed on the degrees to which the rifling devices or chequering devices can be distorted; for the maker must make the bindings or other devices surround the shaft and follow its form, and he therefore must make them so that they lie on the inside of the human barrel.

Besides forming rifling and chequering devices, as has been said, the hands also form clasps. Some simple facts about the riflings and chequerings have been pointed out; and it has been possible to discover the facts because on some types of weapons the devices are partly mechanized. But the clasp devices are not mechanized, and although they can be seen to be formed, little can be learnt about them from direct observations of spear and club machines. The hands form other devices also. They form, for example, trigger devices and trigger spring devices. These devices cannot directly be studied; but after studying the locks of bow and arrow, crossbow, and gun machines, some elementary knowledge about them can be obtained. It may be mentioned that the trigger devices and the trigger spring devices, although formed always when a spear shaft is grasped, are not operated, unless the spear is released or thrown. It is unlikely that more than a very few of the devices formed by the hands as they grasp the grips of weapons have yet been mechanized, and it is improbable therefore that their existences can be realized.

The tilting lance was blunted as early as 1252[13] to try and minimize the danger of accidents. Soon afterwards the head was often provided with three or more short points, so that it somewhat resembled a coronet; and this type of head became known as a coronel. A lance with several short points besides being less likely than one with a single point to find an opening in an opponent's armour has a certain amount of "bite", and is not so likely to slip off the opponent's helmet or shield as one with a blunt head. The several points of the coronel form types of short mechanical fingers; and since they are at the end of the shaft opposite the juster's fingers, it is evident, by Rules 1 and 8 that they are transferred mechanical extensions of the juster's fingers. A coronel with three or four fingers can "grasp" or obtain more bite on an opponent than a single pointed head, in much the same way as three or four human fingers can grasp an opponent better than a single outstretched finger or device formed by all the fingers brought to a point can grasp him. The head of a lance with one point only is a mechanical extension of the device formed by a finger, probably the forefinger, pointing at the opponent as if to thrust at him, or of the device formed by all the fingers brought to a point and used as a thrusting device. A blunt head of a lance is a distorted mechanical extension of the fist, or more probably of a knuckle. A coronel is a mechanical extension of the device formed by several fingers formed as if to thrust at and "bite" on an opponent. Each mechanical device is, of course, in a transferred position, and separated from the wielder's fingers by the length of the shaft.

[13] Sir Guy Laking, Bt., C.B., M.V.O., F.S.A., *European Armour and Arms*.

CHAPTER 17

THE SWORD

A SLASHING weapon can be formed by the hand and forearm, or hand and whole arm. This human weapon is probably the prototype from which the slashing or cutting sword has been developed.

It is difficult to notice correspondences between the human slashing weapon and the sword from resemblances of shapes, unless the sword is leaf shaped as is the case so often in Bronze Age and Early Iron Age swords. But since a weapon cannot have any movements or actions of its own, and since all its movements and actions are merely continuations or extensions of those made by the wielder, some help in deducing correspondences can be obtained by studying the actions of the arms when a sword is being wielded.

At the moment a cut or slash is being made with a sword, usually the arm is fully outstretched, and sword blade and wielding arm are in one line. This reveals that the blade forms an extension for the arm. A cut or slash cannot be made effectively with a sword without a "draw". This applies to all cutting instruments. If a razor edge is made to hit the palm of the hand no harm may be done; but if it is drawn across the palm even very slightly it will probably cut the skin. Circular saw and chaff-cutting blades are made circular so that the principle of the draw can automatically be used so that the blade will cut and not hit. European swords are mostly straight, but Eastern swords are more often curved so that automatically they will draw along the opponent and cut and not merely hit him. The European is advised in manuals on swordsmanship to have the arm as fully extended as possible when the cut or slash is begun so that a draw must almost inevitably result as the

action continues [1] It is to be observed that the draw is made primarily by the arm and is communicated to the sword blade; and when a cut or slash is made the mechanical extension merely continues and extends the actions of the arm. Also, since the blade is distorted so that its side is reduced to a fine edge, the cutting or slashing actions of the side of the arm which are very small are enormously magnified.

The power to distort the blade or mechanical extension of the arm has been obtained only after the resources and ingenuities of weapon makers have been exerted for centuries; and it was only after the use of metals that it became possible to distort and magnify the slashing powers of the arm to any great extent.

Wooden swords are made; but these allow the cutting or slashing powers of the arm to be very little magnified. The wooden sword is indeed often used as a club. It is not possible to make and keep a wooden edge very thin and sharp; and until metal was used for swords little progress was made in magnifying the cutting and slashing powers of the wielding arm. A wooden sword probably smashes rather than cuts, much as an arm might do, and H. S. Cowper remarks, " . . . the wooden or bone swords which travellers have told of, are in reality only either edged clubs meant to inflict a gashing blow, or else mere copies of European swords of metal." [2]

A sword with a point and an edge combines the principles of the spear and the cutting edge, and is really a double purpose weapon, in somewhat the same way as a halberd is a many purpose weapon; but the point and edge combine rather more successfully in the sword than in the halberd. But a double purpose weapon is seldom or never thoroughly satisfactory; and Ffoulkes remarks that "it is remarkable to find that after many hundreds of years of experiment the swordsmith has failed . . . to produce a sword which is equally perfect for the cut and for the thrust," and later

[1] The Rt. Hon. The Lord Headley and C. Phillipps-Wolley, *Broadsword and Single-Stick.*
[2] *The Art of Attack.*

adds, "a really practical cut and thrust sword is a dream that can never be realized."[3]

The hilt, or grip, of a sword is usually in the same line as the axis of the blade. When the sword is fully drawn back over the head, the blade may be about at right angles to the line of the forearm, but is turned through a right angle by the time the cut or slash is made. The grips of some swords like the Indian katars are fixed at right angles to the blade, and therefore are at right angles to the line of the forearm as the thrust is being delivered. The katar is used only for thrusting, and the thrust is given at right angles to the barrel of the hand.

H. S. Cowper believes the pata has been developed from the knuckleduster by way of various types of katars. If his theory is correct, the point of the katar is a much distorted artificial knuckle brought to a point. Parts of the hilt of the katar, formed by the side bars, are parallel to the blades. The gauntlet is a defensive contrivance corresponding to the skin of the hand, wrist, and forearm.

The reader will of course understand that one type of weapon does not develop from another type; but sometimes it is possible by studying weapons without reference to the machinery of the body which wields them to see some sort of evolutionary process at work. Thus, as H. S. Cowper has pointed out, it is possible to see some sort of evolution of the pata from the knuckleduster. Many other students of weapons have tried, without taking into account the complementary parts of weapons formed by the body, to trace the evolution of one type of weapon from another type. But when no account is taken of the complementary parts of weapons formed by the body, inevitably attempts to show that later types of weapons have evolved from earlier types fail because the "missing links" formed by parts of the body cannot be found. When weapons are studied with respect to the wielding machinery of the body, all the "missing links" between the different types of weapons can

[3] Charles Ffoulkes, C.B., O.B.E., O.ST.J., Hon.D.Litt. (Oxon), *Arms and Armament.*

easily be found, or more correctly there are no such things to be discovered as "missing links".

The barrel for the hilt of a sword is formed by the fingers, and in much the same way as for the shaft of a thrusting spear. The breech is formed by the main part of the hand, the palm forming the inner surface of the breech. If the sword is a one-handed sword, the barrel and breech are formed only by one hand directly, but if it is a two-handed sword by both hands directly.

The grip is often approximately cylindrical, but sometimes swells towards the middle, so that it is of larger girth there than elsewhere; and a type of barrel is then formed which is intermediate in type between the spherical type formed when the hand holds a ball shaped weapon and the cylindrical type formed when it holds a weapon with a cylindrical grip. When the hand holds a cricket ball, tennis ball, golf ball, croquet ball, bowl, billiard ball, marble, athletic shot, or other spherical weapon, it automatically and necessarily forms parts of a sphere, but when it holds a halberd, pike, thrusting spear, javelin, arrow, loggat, cricket bat, hockey stick, or other weapon with a cylindrical grip, it forms parts of a cylinder. The barrel for a sword, whose grip swells towards the middle, has therefore some of the features of a spherical and of a cylindrical barrel. If the swelling is very pronounced, features of a spherical barrel are better produced and features of a cylindrical barrel less well produced than when the swelling is not so pronounced.

The barrel for a club whose grip swells towards the middle similarly will have features both of a spherical and of a cylindrical barrel. Thus, the barrel for the life preserver shown in Figure 10 will have features of a spherical and of a cylindrical barrel.

The grip of a dagger is sometimes cone-shaped; and the interior of the human barrel takes the shape of a cone when this type of dagger is held. Conical barrels are also formed to hold a golf club, croquet mallet, billiard cue, and other types of weapons with conical shafts or handles.

Methods of mechanizing the barrel for the hilt of a sword

follow fairly closely those used for mechanizing the barrel for the shaft of a thrusting spear. A tube extension for the human barrel may be provided by covering the hilt with leather, fish skin, canvas, linen, velvet, horn, or other similar types of materials. A tube barrel is also commonly formed by a cord or wire binding; and the mechanical part of the barrel is then rifled by the spiral groove between the turns of the cord or wire. The tube formed by a cord or wire is rifled both on its outer and inner surfaces, and if the hand is placed on it, the interior of the human barrel receives impressions of the spiral and becomes rifled with the mechanical rifling as well as with its own human riflings. The mechanical rifling does not match or fit into the human riflings, and is a very rudimentary and crude reproduction of them. The hilt may be covered both with a cord or wire binding and with a smooth tube of leather, fish skin, or other material; and the cord or wire binding is sometimes over and sometimes under the smoother tube. When the cord is wound over, say a fish skin covering, the fish skin covering becomes rifled on its outer surface by the cord, and the human barrel also becomes rifled by the cord. When the cord is under the fish skin, the fish skin tube becomes rifled on its inner surface, and on its outer surface receives impressions of the human riflings.

The hilt of a sword is sometimes left bare; but the wood, bone, horn, steel, or other material of which it is composed, is often fluted or grooved, and the flutes or grooves form types of riflings. Wide grooves to receive the fingers are made on some grips, each finger having its own groove, and attempts are then obviously made to reproduce mechanical counterparts for the human riflings, for the fingers fit into the grooves, and the ridges between the grooves fill or partly fill the spaces between the fingers. If the grip is hollow, the hollow of the fist is reproduced within the barrel.

The hilt is sometimes circular in section, but may be square, oval, hexagonal, or octagonal in section, or have a section of some other simple geometrical shape. A hilt with

say, an octagonal section automatically rifles the human barrel with eight grooves.

The pommel, or knob at the end of the hilt, is nearly always well formed. The pommel, which derives its name from a fancied resemblance to an apple, is a mechanical reproduction of the fist transferred to the butt of the weapon, and lies against or nearly against the fist.

The human fist is deeply fluted on its outer surface by the grooves between the fingers. It has some remote resemblances to a ball. With the wrist it has some resemblances to a pear or a fig. The part of the fist between the wrist and lower knuckles is somewhat cone-shaped. Looked at from the palm side, the wrist and fist have a marked resemblance to a fish's tail. The fingers form types of disks placed parallel and against each other. All these and many other peculiarities and features of the fist are commonly reproduced by the pommels of swords and daggers.

The pommel is often approximately in the shape of a ball; and is often fluted or grooved. The butt of a pistol also often ends in a ball, much like the ball pommel of a sword, to which it is closely related. The pommel often takes the form of a pear or fig or fish's tail, and is nearly always then fluted or grooved. It often takes the form of a wheel or one or two or three disks. Thus a German dagger in the Wallace Collection has "a circular pommel composed of three disks —the bottom one of brass, the middle of steel, and the top of copper gilt."[4] These disks, since the pommel is a mechanical copy of the fist, are clearly copies of the disks formed by the fingers of the fist, distorted into the regular forms of disks. They are therefore related to the disks of the ancient Greek caestus; but the leather disks of the caestus correspond more closely in materials to the materials of the human disks than do the metal disks of the dagger. The caestus disks compared with the pommel disks are turned through a right angle (Rule 10), for they lie approximately in the plane that includes the axis of the barrel, but the disks of the pommel lie in planes at right angles to the

Catalogue, *European Arms and Armour*, 1924, No. 114.

axis of the human barrel. The pommel reproduces the cone-like form of the lower part of the fist when it is made in the form of a cone. The cone is sometimes inverted or reversed (Rule 11). If it is made of hexagonal or octagonal section, six or eight riflings are formed by its ridges. These riflings are not impressed on the human barrel when the grip is held, but are impressed on it when the pommel is held.

The pommel often ends in a button. The button is an embryonic mechanical knuckle transferred to the side of the pommel opposite the human fist (Rule 8). In the club machine usually the greater part of the mechanical extension of the fist is transferred to the end of the mechanical extension of the arm to form the head of the club, but a small part may be transferred to the butt of the grip to form a rim or knob which helps to prevent the club slipping through the hand. The fist of the sword cannot be so transferred, or the sword would have a large knob at its point and could not then be used to give a thrust or cut. But a small portion of the mechanical fist is transferred to the point when a button is placed on the point of a fencing foil to prevent injury to an opponent. The button on a pommel is therefore evidently related to the button on the point of a fencing foil. The button on a fencing foil is at the point end of the weapon: that on a pommel at the hilt end.

The quillon, or bar projecting from the sword where hilt and blade meet, is primarily a defensive and not an offensive device. Its human prototype can be easily discovered, by considering its use. It serves to protect the swordsman's fingers and hand and forearm from his opponent's cuts or slashes, and guards his body in somewhat the same way as the left forearm of the wielder of a single-stick or cudgel guards his body. It is therefore a type of mechanical left forearm. It is at right angles to the mechanical extension of the right arm, formed by the blade.

The wielder of the fists, boxing gloves, single-stick, cudgel, shillalah, walking stick, or umbrella, often uses his left forearm to parry the cut or blow of the opponent; and commonly the device formed by the left forearm is at right angles

to the axis of the weapon or to the direction given by a blow from the fist or glove. It is also at right angles to the barrel of the left fist, and when mechanized is at right angles to the barrel holding the hilt. The old time wielder of the single-stick or cudgel made a kind of fixed parrying device of his left forearm, which could not then move relatively to his body, by passing a scarf, tied into a loop, under his left leg and holding it tight with his fingers, so that the left elbow was always about the height of his head with the left forearm guarding the left side of his head and body.* Although his arm may have been tough enough to stand the whacks of a single-stick or cudgel, no forearm can stop the cut or slash of an edged weapon; and a guard formed by a human device is unsuitable for use against the swordsman. So the swordsman mechanizes the left forearm in the form of the quillons, and the mechanical extensions of course can guard him against an edged weapon. Since the quillons are defensive devices, they are not edged as the blade is edged. They are often fluted or twisted spirally, and often also end in knobs which are rudimentary forms of fists transferred to their ends. The elbow is often represented and reproduced in mechanical form by the bend in the quillon. The quillon has an offensive use when a finger is placed over it, to secure the hilt more firmly to the hand and the more easily to direct the edge of the blade for a cut. A study of quillons however belongs more properly to a study of armour than of arms.

The blade of the sword it seems is usually a mechanical extension of the hand and arm. The mechanical extension of the hand can fairly evidently be seen in the wide part of the leaf-shaped sword common in the bronze age and in early Greek times; and the mechanical hand is at the opposite end of the sword to the human hand. The position of the extension of the hand, if the hand is mechanized, on a straight edged sword is difficult to discover. The blade of a sword is usually described as in two parts, the forte nearer

*For an illustration, see Lord Headley and C. Phillipps-Wolley, *Broad-Sword and Single-Stick*, ch. IV, page 61.

the hilt and foible nearer the point, but there may be nothing to show where these parts meet. The two parts possibly are extensions of the forearm and upper arm, but this cannot be stated with certainty. Possibly also the mechanical extensions of the forearm and upper arm are reversed on some swords compared with their positions on other swords. The hand is almost certainly mechanized as the part of the blade near the hilt on the cinquedea, because the width of this part of the blade is supposed to be the width of five fingers of the wielder. The cinquedea is a type of weapon intermediate between a sword and a dagger, with a blade widest nearest the hilt and of a somewhat triangular shape, the apex of the triangle opposite the hilt forming the point. According to Laking, "its very name has reference to its form, the word cinquedea or sanquedea being derived from two Italian words, *cinque*—five, *dita*—fingers; . . . for it will generally be found that the blade of the cinquedea is from three to four inches wide at the hilt."[5]

Because the dimensions of parts of weapons are related to those of their human counterparts, it should always be possible to state the dimensions of any part of a weapon with reference to its human counterpart. A natural system of measurements would then be used, which would have the property of varying its units to suit the dimensions of each person. To say the width of the cinquedea's blade should be equal to the width of the five fingers of its wielder is to use a natural system of dimensions of the greatest convenience, for the system allows for the variation in the width of the blade to suit each person's dimensions. The width of the blade cannot be stated in any system of measurements with fixed units; and a system with fixed units cannot allow for each person's different dimensions, except by vagueness of statements as for example by saying the blade should be from three to four inches wide, or by the complicated process of using different measurements for each person. If it is said that the blade should be equal to the width of the

[5] Sir Guy Laking, Bt., C.B., M.V.O., F.S.A., *European Armour and Arms.*

five fingers, no one is in doubt about the width the blade should be made to suit himself.

Even in the present small state of our knowledge of weapons, it is frequently possible to state the dimensions, powers, positions, and other characteristics of parts of weapons in the natural system with some degree of accuracy and often quite accurately. Thus, the distance between the two rings of a knuckleduster can be stated as equal to the distance between the forefinger and little finger; and this statement gives each person the right measurement for the distance between the rings. The distance cannot be given in the British or metric systems, whose units cannot vary, except by stating the distance separately and differently for each person. The girth of the interior of the Greek caestus is equal to the girth of the hand. The girth of the interior of the thongs of the caestus wound round the wrist is equal to the girth of the wrist. The length of the butt of the rifle is equal to the distance between the shoulder and the trigger finger. The diameter of the smooth shafted spear is equal to the bore of the human barrel. The centre of a ball held in the hand is at the centre of the human barrel. The power in the bow at any moment during the drawing of the bow is equal to the power exerted by the archer's arms. The blade of a katar is at right angles to the axis of the human barrel. And so on.

Similarly, the dimensions of parts of other types of mechanical instruments can be stated in terms of their human counterparts. Thus, the length of the inside of the forefinger of a glove is equal to the length of the forefinger; the inner girth of a hat to the girth of the head; the girth of a stocking at any part of the calf is equal to the girth of the calf at that part; the girth of the butt of a cigarette is equal to the length of the circumference of the barrel formed by the lips; the diameter of the barrel formed by the fingers as they hold a pencil or pen is equal to the diameter of the pencil or pen; and so on.

The natural system used above and much used throughout this work provides that automatically the different standards

of persons shall be allowed for. Every person in the world has a different system of units. Furthermore the units of each person are constantly changing, as all mothers know. Fixed standards systems have the weakness that their units cannot vary either together or with respect to each other. They therefore do not suit anybody. Since no two persons have the same units of measurements, a prime requirement of a system of measurements is that its units shall be capable of varying automatically to suit the units of each person. The natural system, or nature's system, alone has this unique and essential property.

The best known artificial systems of today are the British and metric systems. The British system it seems was intended originally to be based on the natural system, as the retention of words like foot and hand shows. But the lengths of the inch, foot, yard, etc., have been fixed, and cannot now vary together or with respect to each other. The metric system was meant to be the ideal system for the mechanical age ahead. But its inventors were unaware that the dimensions of parts of machines are related to dimensions of parts of the body; and tried to relate all measurements to the length of a quarter of the earth's circumference. This length was incorrectly measured by the inventors, and the units of the system therefore are not based on anything in particular; and this system is probably the least scientific system in use today.

Systems of measurements based on fixed units can have only a very limited use in everyday affairs; and indeed the British and the metric systems break down continually in trade and commerce. They are therefore commonly ignored, and the natural system is used instead. Thus, when a person wishes to buy a pair of shoes or a garment, he ignores the artificial systems and demands that his own standards of units shall be used. A woman when buying a pair of gloves ignores the British or metric system; and adopts the natural and more satisfactory method of trying on a few pairs to discover which of them corresponds most closely to her own system of units. A glance at a shoemaker's or tailor's note

book would show that each of his customers has his own standards of units different from those of anybody else; and that the shoemaker or tailor is under the necessity of discovering the units of each customer and of transcribing them into the system of fixed units he may use. Often he does not trouble to transcribe them. Thus a shoemaker may make the sole of a shoe directly from a pattern of his customer's foot traced on a piece of paper or on a board, or the tailor or dressmaker may place a garment on the customer and mark its lengths to correspond to the standards of the customer, without making any use of the British or metric systems. The use of fixed standards systems is indeed a main cause of the confusion and difficulties and waste of time experienced in shopping, for it is not possible to state the length of the sole of the foot, width of the foot, length of the arm, girth of the head, or any other human measurement, in a fixed standards system, and therefore hundreds of different measurements must be used in attempts to relate the artificial systems to nature's system.

Although a little study and reflection soon shows that fixed units of measurements are responsible for confusion and waste of time in everyday affairs, and are unsatisfactory, unfortunately our knowledge of nature's system at present is too small for us to be able to use it to any great extent. A study of nature's system however would in time give us the power of using and applying it; and then great advances might be made in obtaining knowledge of nature's works, and in avoiding the confusion and waste of time in shopping.

Since the British and metric systems have little or no relationships to nature's system, they are therefore unsoundly based, and their use almost effectually prevents investigation of natural phenomena. But if nature's system is used, the investigation of natural phenomena becomes a fairly simple matter. Thus, as shown in this work, when the dimensions of weapons and other mechanical contrivances are referred to parts of the body the ways in which mechanical contrivances originate and develop and will develop in future can easily be known

Artificial systems of measurements are crude and rudimentary copies of the natural system, or system used by nature. The artificial systems are extremely complicated: nature's system is, it seems, very simple — probably too simple for us to understand at present. The British and metric systems correspond only very remotely to nature's simple and perfect system. Perhaps they are as poor copies of the natural system as, say, the spear and sword are of the hand and arm As has been said, the units of the artificial or mechanical systems cannot vary to suit the units of different persons: nature's units can do so. No doubt in time the artificial systems will be brought to closer correspondence to nature's system, or new systems will be devised having closer correspondences Thus, gradually the confusion and difficulties and waste of time caused in everyday affairs through the use of fixed standards systems may be removed.

The Rules given in Chapter 14 are of much help in discovering the human prototypes of parts of the hilt of the sword. They also help to show that the blade is a mechanical extension of the hand and arm. But they do not allow it to be understood how distortion of the blade to a fine edge has been accomplished; and it can at present be said only in a general way that the blade is a mechanical extension of the contrivance formed by the hand and arm for thrusting or slashing at an opponent. But it will probably not be difficult for others, in due time, to discover more Rules and solve these and many other problems. In the meantime, by studying weapons with reference to the human wielding machinery and with the help of the Rules that have been obtained, the ways in which different types of weapons have originated and developed and are related, and more important how new types will originate and develop can be known in a general way, and sometimes can be known in detail.

Chapter 18

STONES THROWN BY HAND

ACCORDING to Rule 8 a mechanical part can be transferred from one end of a part of the offensive machine to the other end. A simple example of a transferred part is seen in the head of a club, which is a mechanical extension of the fist transferred from the hand at the grip to the end of the handle opposite the hand. Another simple example is seen in the skin of a modern boxing glove. The skin of the glove is a mechanical copy of the skin of the hand, but it does not rest directly on the human skin, for the padding of the glove is interposed between the skin of the glove and the skin of the hand; and the skin of the glove is transferred from the human skin to the surface of the padding opposite the skin of the hand. The padding itself is also in a transferred position, for it does not lie next to the flesh of the hand, which is its human counterpart, but lies on the outer surface of the skin. Since the flesh is on the inner surface of the skin and the padding is on its outer surface, the padding is a mechanical extension of the flesh transferred from the under to the outer surface of the human skin.

When a weapon, say a stone, is retained in the hand during the wielding actions, the range of the wielder does not much exceed the reach of his arm, and the trajectory of the weapon is short, the trajectory being the line along which the stone is moved from its position at the beginning of the delivery of the blow to the point where the opponent is hit. If, for example, the stone is brought from behind the body, the trajectory extends from the place where the stone was at the beginning of the delivery of the blow to the point where the opponent is hit. When a blow or thrust is given by a weapon which is retained in the hand, therefore, the hitting part of the weapon is moved along its trajectory from

one end to the other, and is transferred from one end of the trajectory to the other, in accordance with Rule 8.

When a blow is given by a club, two trajectories can be observed, one described by the head of the club and another by the fist at the grip. One trajectory is similar to the other in shape, but that described by the fist is smaller than that described by the head and lies within it. If the head of the club at the beginning of the delivery of the blow is above and behind the wielder's head, the trajectory of the head is the curve described by the head as it is brought from its initial position behind the body to the point where it hits the opponent. If the club is swung round the body, the trajectory instead of being in a vertical plane may be in a horizontal plane, or will be in a plane inclined at a certain angle to the horizontal depending on the elevation of the blow.

The curve described by the head of the club is a mechanical counterpart of the curve described by the hand at the grip, and the trajectories described by the mechanical head and human fist are closely related. The curve described by the head of the club can be conveniently called the mechanical part of the trajectory, and the curve described by the fist at the grip the human part of the trajectory. When a club is being wielded the mechanical and human components of the trajectory do not coincide, for the mechanical part of the trajectory lies outside the human trajectory, and is a magnified and often distorted copy of it.

The mechanical and human components of the trajectory often coincide. This happens, of course, when a weapon held and retained in the hand, like a caestus or baghnak, is wielded, because the hand and mechanical weapon cannot have different movements, and the trajectory of the caestus or baghnak must coincide with the trajectory of the human fist or claws.

Frequently human and mechanical counterparts describe part of the trajectory together, and then the mechanical part of the weapon goes forward and describes a part of the trajectory by itself. This happens when, for example, a stone is thrown.

When a stone is retained in the hand, the hand and stone describe the trajectory together, and the hand and stone are transferred from one end of the trajectory to the other in order to deliver the blow (Rule 8). Thus when a stone is held in the hand to club an opponent, the trajectory is the curve described by the hand and stone as they are brought *from behind the body or from over the head to the place* where the opponent is hit. The human and mechanical components of the trajectory coincide during this action.

If a stone is *thrown*, the hand and stone describe the trajectory together from the point where the hand is extended behind the body preparatory to throwing to the point where the stone leaves the hand. The stone alone then goes the rest of the way along the trajectory to the opponent. The complete trajectory consists of the part traversed by the hand and stone together plus the part traversed by the stone alone as it flies through the air. The part of the trajectory described by the stone alone is clearly an extension of the part described by the hand and stone together. The human part of the trajectory consists merely of the part of the curve described by the hand; the mechanical part consists of this part of the curve and also of the part described by the stone after leaving the hand. The mechanical part of the trajectory therefore coincides with the human part at the beginning, but after release of the stone is merely a mechanical extension of the human part (Rules 3, 4, 5).

In technical language, the act of throwing a stone at an opponent or target consists in transferring the stone from one end of the trajectory to the other, that is from the end near the thrower to the end near the opponent or target. For the action to be effective, the opponent or target must be at the end of the trajectory.

The trajectory is formed by a material line when a harpoon with line fastened to it is thrown. When the harpoon is thrown, one end of the line is retained in the hand, and the harpoon does not become disconnected from the wielder's body. As the harpoon is thrown, the line forms the trajectory which is made visible for a few moments, although it rapidly

loses its shape; and the way the harpoon is transferred from one end of the trajectory to the other can be well seen. It can, of course, be transferred only from one end of the mechanical trajectory to the other, and could not be transferred to a position say half or one third of the way along it. The wielder's hand is at one end of the trajectory and the object hit is at the other end.

Since transference of the missile along the trajectory takes place in accordance with Rule 8, the trajectory must be regarded as part of the offensive machine. It forms a link between the wielder and his opponent or target; and when a missile hits an opponent, the thrower may be regarded as transferring it to the opponent by way of the trajectory.

Some understanding of the degree to which mechanization of a human part or action allows the part or action to be magnified or extended is given by considering the degree to which the cords of the arm can be given mechanical extensions by means of the cords of harpoons. The cords of harpoons used by whalers may be several miles in length. Mechanization thus allows the cords of the arms to be extended almost indefinitely, and to be magnified also in strength. Therefore it need not now surprise us that makers of swords and spears, for example, have been able to extend and magnify the cutting or slashing or thrusting powers of the arm or fingers by giving their extensions such thin and keen and sharp and strong edges or points.

The portion of ground between the wielder and his opponent or target must also be regarded as part of the offensive machine, as can be understood from a study of the part it plays in an offensive action. Suppose a long plank floated on water with the wielder standing on one end and his opponent at the other end. When the wielder threw his missile, the plank would begin to move in the direction from the opponent towards the wielder, due to the backward push exerted by the feet of the wielder as he threw the missile. The backward momentum of the plank and wielder and opponent together would by elementary dynamics be exactly equal to the momentum forward of the missile. When the

missile hit the opponent, the momentum of the missile would be imparted to him, and would cause the plank to reverse its direction, until it came to rest in the original position; it being assumed for simplicity that there was no resistance to the movements by the water or air.

The throwing of a missile therefore, it can be seen, has effects on the plank connecting the wielder and his opponent, which can be known and calculated. When, as is usual, both wielder and opponent are on the ground, the ground behaves in a similar way to the plank, but because of the great mass of the earth no movement of the ground can be observed. When a missile is thrown, however, the motion of the earth is affected. Thus suppose the opponents stood along a parallel of latitude. When a missile was thrown by one towards the other, the movement of the missile while it lasted would slow down or quicken the rate of revolution of the earth. When the missile hit the opponent, or ground in front of or behind him, the increase or decrease in the rate of the earth's revolution would be stopped and reversed, and no net increase or decrease would result. These facts are of course known to every student of dynamics, and need not be further elaborated here. But a study of them shows that the ground between two opponents must be regarded as a part of the offensive machine.

The reactions of the ground on the feet are brought into great prominence during a tug-of-war. The reactions of the ground on the soles of the feet of the men must come into play so that the tug-of-war can be held. A tug-of-war could not be held on a smooth surface like ice, for friction between the soles of the feet and the ground is necessary for the power of the men to come into action. The tension in different portions of the rope at any moment depends not only on the forces exerted by the hands but also on the forces exerted by the ground on the soles of the feet.

The reaction of the ground plays a necessary and important part when any weapon is being wielded. When the shot or javelin or hammer or weight or other missile is being thrown the force exerted by the soles of the feet, i.e., the

butt end, on the ground away from the target is equal to the force with which the missile is thrown. It can readily be understood that the nature and state of the ground on which a tug-of-war is held affect the actions and movements of the teams. When a tug-of-war is held in accordance with some competition rules, heels, spikes, bars, or other similar devices, may not be fitted to boots or shoes, and therefore when the ground is slippery the pulling motions are performed with more difficulty than when the ground is not slippery. When a tug-of-war is held on hard, firm soil the movements of the teams are different from their movements when one is held on soft yielding ground.

The nature of the ground between a wielder of a weapon and his opponent or target affects his actions and movements. According to W. M. Smith, "The nature of the turf and subsoil has a great deal to do with the length of an athlete's throw. On firm, wiry grass, forming a spongy turf, resting on porous subsoil, an athlete, other things being equal, will put the shot better than on soft grass on close, rich soil." [1] Players of the game of cricket pay great attention to the state of the ground between the wickets, and the condition of the pitch during the course of the game is a matter of concern both to the players and the spectators.

The trajectory and the ground act in a manner somewhat analogous to the manner in which an electric wire and the ground act when a current is transmitted. The ground can be used as the return circuit when a current is sent along a wire, that is when an electric action is transferred from one end of the wire to the other (Cp. Rule 8). The trajectory somewhat similarly can be regarded as the means by which an offensive action can be transmitted, and the ground as the return circuit for the action.

When a stone is thrown, a mechanical counterpart of the fist or of part of the fist is thrown. When a club is thrown, mechanical counterparts of the wielding arm and fist are thrown, or transferred to the end of the trajectory opposite the thrower. Many machines throw only a part of a weapon.

[1] *The Athletes and Athletic Sports of Scotland.*

Thus, the bow and arrow machine throws only the arrow; and the bow and strings are not thrown. The rifle machine throws only the bullet, and the rifle itself is retained in the hands. The whole of the mechanical weapon is therefore transferred along the trajectory by some machines, but parts only of it are transferred by others.

The offensive machine is only slightly mechanized by means of a missile stone; and therefore little can be learnt about the stone throwing machine by direct study of its form and actions.

It can be noticed, in a general way, that the form and actions of the machine depend largely on the size and shape of the stone. Types of missiles vary from a small pebble to the 16lb. stone ball of the stone putter or the heavy boulder thrown by the ancient Greek athlete. The actions of the thrower of a small pebble are very different from those of the stone putter; and it is clear that variations in the weight and shape of the stone profoundly affect all the mechanisms of the machine. Fundamentally, however, the actions and movements of all types of the machine are the same.

When a small roundish stone or ovoid pebble is being thrown, it is held by the first fingers and thumb which reproduce the shape of the pebble where they are in contact with it. When a 16lb. stone is being putted, the missile is held more against the palm and against the parts of the fingers near the palm.

As has been indicated, the human prototype of the mechanical barrel is the barrel device formed by the fingers as the hand is clenched to form a fist. The human prototype of the mechanical breech is the pouch device formed by the palm.

A small stone therefore is held mainly in the barrel of the throwing hand; but a heavy stone more in the breech, although it is held also partly in the barrel. The barrel and breech of the stone throwing machine are not mechanized, and are formed only by human parts.

As has been pointed out, the barrel of the fist machine is formed partly by one hand and partly by the other. Similarly

the barrel of the stone throwing machine is in two parts, one formed by the left hand and the other by the right hand. The stone is held directly only in one part of the barrel, viz. that formed by the right hand if the thrower is right handed; but the other hand helps to balance and control the right hand; and the free hand is not kept open but nearly always imitates the type of fist formed by the hand holding the missile or weapon.

The length of the barrel varies during the wielding of the stone, since the distance between the hollows of the fists varies. The length of the barrel is at a minimum usually at the beginning of the movements when both hands are placed together. The hands then separate, and the barrel increases in length until, with the left hand stretched forward and the right hand with the missile in it brought back as far as possible, the length of the barrel is at a maximum. The hands are then reversed, and the right hand goes forward and the left hand comes back. A maximum length is again reached at the moment of release, because then the right hand is stretched out and the left hand is brought back as far as possible.

In the days of muzzle loading guns, the missile was put in at the muzzle and pushed down the barrel. As the gun was fired the missile moved from the back of the barrel to the muzzle. It can be seen that somewhat similarly as a stone is being wielded, it is moved first from the muzzle of the barrel to the back of the barrel, and then as it is being thrown moves in the opposite direction and travels from the back end of the barrel to the muzzle. How this happens can be explained as follows:—

The fore part of the barrel is formed by the hand which at any moment happens to be at the front. At the beginning of the movements both parts of the barrel are together. As the hand with the stone in it is brought back, it forms the rear part of the barrel, and the stone is therefore brought back into the rear part of the barrel. But as the right hand goes forward to throw the missile it ceases to form the back part of the barrel and forms the front part; and the stone is

therefore moved from the back part to the front part of the barrel; and at the moment of release the stone is propelled from the muzzle, or fore part of the human barrel.

The movement of the stone from the back part to the front part of the barrel as it is being propelled corresponds to the movement of a bullet from the breech to the muzzle of a gun barrel as it is being shot. The action of the right hand in moving the missile to the back part of the barrel is analogous to that of the gunner's hand when he pushes his missile down the barrel with a ram-rod. The rod forms an extension for the rigid parts of his arm. This extension is distorted in diameter so that it can be pushed down the barrel. Th. ram-rod was sometimes fired by mistake, especially in the excitement of a fight when it was left in the barrel by an inexperienced gunner. The gunner then shot an arrow type of missile.

The power to throw a stone is generated, it can be seen in a general way, by separating the hands and expanding the chest. At the beginning of the movements the hands are usually placed nearly together, and just before throwing the missile they are separated and the chest is fully expanded. This is the method by which power is generated by many other types of offensive machines, notably by the bow and arrow machine. The archer's hands are nearly together before he draws the bow. To generate power he separates his hands, and expands his chest, until the bow is fully drawn and full power is obtained.

When a stone is so large and heavy that it must be held and wielded by both hands, the hands cannot be separated to generate the power, and it is generated therefore usually by the wielder making a part of a turn, a full turn, or several turns, and bringing centrifugal force into play.

Just before a pebble is thrown, the stone thrower's hand is drawn back and his left hand is stretched forward. This is an aiming position, and the line from the right hand to the left shows the proposed direction and elevation, as it does when the bow and arrow, rifle, spear, club, or other type of weapon is being wielded. To throw the stone, the thrower

reverses the positions of his hands, and his right hand goes forward and his left hand comes back; and at the moment the stone leaves the hand, the line from the left or rear hand to the right or forward hand then shows the direction and elevation of the blow. The direction and elevation line is thus suddenly reversed.

The actions of the feet are somewhat similar to those of the hands. When the right hand is drawn back preparatory to being thrust forward the line from the right foot to the left shows the proposed direction of the blow. When the hands are reversed, the feet are reversed also, and as the stone leaves the hand, the line from the left foot to the right then shows the direction of the blow.

Before the right hand is brought to the front, sometimes the wielder's left foot is raised; and the line from the rear foot to the front foot then also shows the proposed elevation. The shot putter's attempts to find the correct elevation can be seen as he waggles his left foot above the ground in front of him when aiming the shot.

Release of the stone is effected by relaxing and straightening the fingers; and as the missile leaves the hand, the fingers point along the trajectory in the direction of the blow.

The violence of the recoil depends a great deal on the weight of the stone, and is much less when a small pebble is thrown than when a heavy stone or boulder is thrown. The recoil when a boulder is thrown is so heavy that it is only with difficulty and after much practice that the athlete can prevent himself being thrown by the boulder.

Nearly all the mechanisms of the stone throwing machine are human. The only part that is mechanized is the fist, the stone being an artificial and very crude extension of the fist; unless it is very large and heavy when it may be a mechanical reproduction and extension of part of the body. The stock, barrel, butt, heel-plate, pivot, sights, power charging apparatus, and most other parts of the machinery of the stone thrower are all human; and therefore cannot easily be studied. But after a study of more highly mechanized types of the offensive machine, it can be realized that the stock is

formed by the stock of the body, the butt by the legs, the butt end by the foot or feet, the heel-plate by the sole of the foot or shoe, the sights by the hands, and so on.

The stone throwing machine is not much used by any civilized people. In England the only time it is developed to any extent is during competitions in throwing the cricket ball, the missile then being modified in materials and not then being of stone. Stone throwing is practised by the Niue Islanders, the missile being about the size of a cricket ball, but oval in shape and made from stalagmite. The Fuegians carry spare stones in the corners of their little skin mantles, and are expert stone throwers. It is related that a Fuegian attacking a ship's crew which had wounded him, flung stones with such truth of aim that the first struck the master of the ship and smashed his powder-horn to pieces, and nearly knocked him down. The next two were hurled at the heads of the nearest seamen, who just escaped by stooping as the missiles were thrown. Some time before this event the sailors had been astonished at the stone throwing powers of the Fuegians, who nearly struck them with stones thrown by hand when they thought themselves even beyond musket-shot range.[2]

[2] The Rev. J. G. Wood, M.A., F.L.S., etc., *The Natural History of Man.*

Chapter 19

ATHLETIC MISSILES

The Shot

THE shot putter's missile is an iron ball usually weighing 16 lbs. It is too large to be easily grasped by the fingers; and to prevent it escaping from the hand during the wielding movements, the palm is held nearly horizontally, and the shot rests on the part of the hand where the palm and fingers meet, the weight being borne where the three middle fingers join the hand. The fingers and thumb curl partly round the shot and keep it in position.

The shot is a mechanical copy or extension of the fist, for it rests in the hand which is partly clenched to receive it (Rules 1, 3 and 7); it bears a rudimentary resemblance to a fist (Rule 1); during the wielding movements the clenched hand and shot move together and cannot have different movements (Rule 4); the shot relieves the human fist of the need for directly delivering the blow (Rule 5); and the type of blow given by it is one that somewhat resembles a type that might be given by the fist (Rule 4).

A composite fist is formed by the shot and the partly clenched hand. A human part is formed by the hand and fingers, and an artificial part by the shot. The artificial part is homogeneous, and composed only of iron: the human part is not homogeneous, but is composed of many different materials, some being soft and some hard; and the shot therefore reproduces only a few of the features of the human fist.

The back of the composite fist is formed partly by the hand and partly by the shot, the raised portions being formed by the hand and fingers, and the parts between the fingers by the shot. The knuckles, finger joints, and finger nails, are formed much as in the bare fist; but the knuckles are not so sharply formed. The finger nails, which are nearly hidden

in the unmechanized fist, can be plainly seen. The ball of the thumb is rather more visible than in the unmechanized fist.

The part of the fist opposite the back of the hand is formed almost entirely by the shot, and is part of a sphere. The fingers are wide apart, and not together as in the bare fist. The thumb lies against the shot and not against the fingers. The shot is a very elementary copy of the fist; and is greatly distorted in size and materials. It is also much distorted in shape, for it is spherical, and the fist is far from spherical.

The shot is wielded directly by the right hand; but also indirectly by the left hand, because the left hand balances the right and helps to control it; and the movements of the left hand are closely related to those of the right hand.

The barrel has a minimum length as the shot is picked up and held by both hands. The ram-rod action can be seen as the putter brings back the shot to its fullest extent, bringing his right shoulder back at the same time. The shot is then in the back part of the barrel. It moves from the back part of the barrel to the front part as it is being putted, because the right hand then moves forward and forms the front part of the barrel, the back part then being formed by the left hand which previously had formed the fore part of the barrel.

The fastenings which hold the shot to the hand are not very effective. The fingers and thumb curl partly round the shot and form clasps; but they cannot curl far enough round to hold it, and it must be held to the hand by the hand being placed palm upwards. The shot is not provided with projections or indentations; and therefore most of the fastenings must be formed by the hand and fingers.

The shot lies mainly in the breech of the hand, i.e., mainly in the lower part of the pouch of the hand. The heavy shot impresses its shape on the palm, and parts of the surface of a sphere are reproduced on the interior surface of the human breech. (The interiors of the breeches of many old fashioned guns, similarly, are parts of spheres). The shot is also held by the fingers, and therefore lies also in the barrel of the

hand, which is formed by the upper part of the pouch of the hand. The shot therefore rests partly in the breech and partly in the barrel of the fist.

The shot is not used directly against an opponent, but is aimed at a target representing him. This target, the author has shown in a previous work, is formed by the ground outside the circle in which the athlete stands. The opponent, or target representing him, is at the end of the trajectory of the missile, and is hit with a heavy blow, and may be said to be clubbed; and there is little difference between the type of blow given by a spherical stone held in the hand or by one given by the rounded head of a club and one given by a shot.

The recoil is very pronounced, and the athlete must be careful to make compensating movements to take and absorb the recoil, or instead of throwing the missile he may be thrown by the missile. The recoil absorbing machinery is not mechanized and is wholly human. That is, the athlete is not provided with any mechanical springs or buffers to help to take the recoil, and his body must form the springs and buffers to take the recoil. The shock of the recoil, it is easy to see, is transmitted to his body and then to the ground.

Release of every type of projectile is effected by straightening and relaxing the fingers or a finger; or by the converse of these actions. Thus, the archer releases his arrow by relaxing and straightening his fingers; but the rifleman reverses these actions, and sets free his bullet by curving his forefinger and making it taut (Rule 11). When a gun is fired by a person pressing a button with a finger, the finger which is relaxed before the missile is fired is suddenly curved and made taut, the action being similar in principle to the action of the rifleman, though modified slightly. The release mechanism of the shot putter is not mechanized; and release is effected mainly by the shot passing out of the control of the fingers, which however are relaxed and straightened at the moment of putting, in accordance with the universal practice.

The rifling or spinning mechanisms of the shot putter are not mechanized. The human riflings are formed by the grooves between the fingers, which are in the shapes approximately of wedges or triangles, and by the creases on the insides of the finger joints, which form approximately parts of circles round the sphere. As the rifling devices are not mechanized, it is difficult to discover how they are constructed and how they work. The devices are manipulated, however, for the fingers give a final "flick" to the shot as it leaves the hand, and thus impart some spin to it.

The Cricket Ball

The fist can be partly mechanized by means of a cricket ball. The ball is spherical, and weighs about 5½ ounces. It is not as large or heavy as the shot, and is held usually by the thumb and first fingers and upper part of the palm; but many other methods of holding it are used, especially by bowlers. Sometimes it is held mainly in the barrel, that is by the thumb and fingers, sometimes it is held more against the palm, that is more in the breech of the hand.

The mechanical part of the fist is formed by the ball, and reproduces features of the fist rather more closely than they are reproduced by a stone or by a shot, for the surface of the ball is of leather and therefore corresponds fairly closely to the surface of the fist in materials, the fist being covered with skin and the ball with skin made into leather. The materials of the interior of the ball have some remote correspondences to those of the fist, for the padding which fills the ball very remotely reproduces some of the features of the flesh, notably its resiliency.

No very close correspondences can be expected to be seen between simple objects like a stone, shot, or cricket ball, and such a complex organism as the fist, for no nearly homogeneous object can reproduce more than perhaps the shape and size and weight of the fist with any degree of fidelity. Simple objects like the stone, shot, and cricket ball are extremely primitive and elementary derivatives of the fist. It will be seen later that the most complex and developed weapons are

more distantly related to their human counterparts than parts of embryos of creatures are related to fully developed parts. It is not strange therefore that correspondences between primitive types of weapons and their human counterparts are sometimes not easy to observe, but remarkable that correspondences can so often and unmistakably be seen. Thus, the surface of the cricket ball can be seen, especially with help from the Rules, to reproduce, very distantly it is true but quite unmistakably, the skin of the fist in an artificial form, the fist being covered with skin and the ball being covered with skin made of leather. The ball also is spherical in shape; the fist also is somewhat of a spherical shape; and so on.

Of course, it would not be possible to believe that a cricket ball reproduces features and characteristics of the fist, from a comparison of the cricket ball and fist alone. But, as every *part of every weapon can after some study be seen to have* features and characteristics of a human part of the offensive machine, and since as might be expected the features and characteristics nearly always show closer correspondences in more complex and developed weapons than in simpler and more primitive weapons, it can be known with certainty that the cricket ball is a derivative of the fist, that the shot is also a derivative of the fist, and similarly the stone held in the hand is a derivative of the fist.

Control over the composite fist, formed by the cricket ball and the fist in which it is held, is helped by movements of the other hand, for the other hand balances the one that holds the ball. The parts of the hand and fingers in contact with the ball reproduce its shape and take the impression of the seams and stitches, the seams and stitches where they cross being approximately at right angles.

The riflings are partly human and partly mechanical. Human riflings are formed by the spaces between the fingers and by the creases across the insides of the finger joints and these tend to form spirals. Mechanical riflings are formed by the seams and stitches, which are crude mechanical reproductions of the human riflings, transferred from the human

devices to the surface of the ball (Rules 1, 3, 7); and the cricket bowler makes the human and mechanical devices work together when he spins the ball, the fingers gripping the seams and stitches to produce spin.

Release of the ball, when it is thrown in competitions, is effected by straightening the fingers. The recoil is not as powerful as when the shot is put, for the cricket ball is not as heavy as the shot.

The Javelin

The javelin is a spear type of missile. It is made of wood with a sharp metal point, and is about 8ft. 6ins. long. It has a binding of whipcord at the middle where it is held by the hand.

From its length, the shaft is evidently a mechanical reproduction of both arms, placed end to end. It is in one piece, but the binding helps to show where one mechanical arm ends and the other begins. The shaft is thickest near the binding, and tapers to the front end and to the rear end; and the arms of the javelin therefore correspond in directions to those of the wielding arms in the aiming position, when one arm is stretched forward and the other behind. The shaft is held in line with the human arms, whatever the elevation.

The javelin is gripped at the binding by the right hand and fingers so that the binding lies against part of the palm and the insides of the fingers. Two barrels can be distinguished, one formed by the binding to contain the shaft, and the other by the fingers to contain the binding and the shaft.

The barrel formed by the whipcord is very nearly cylindrical, and both its inner and outer surfaces are rifled by the spiral groove between the turns of the binding. The whipcord as it is placed on the shaft necessarily takes the shape of the shaft; and a cylinder of whipcord is made to contain the middle part of the shaft, where the ends of the mechanical extensions of the arms meet. A continuous spiral is formed between the turns of the binding, and the rifling has a pitch depending on the thickness of the whipcord; and there are

fewer turns of the spiral, or rifling, to each inch of binding when thick whipcord is used than when thinner whipcord is used. If the shaft could be removed from the whipcord cylinder without altering the shape of the cylinder, and we looked through the binding we should see a rifled cylinder which conformed exactly to the shape of the middle of the shaft. The shaft has no movement relative to the whipcord barrel, and both are thrown together.

The fingers form a human barrel to hold the whipcord cylinder and the shaft contained within it; and parts of a rifled cylinder are formed by the fingers. Because of pressure between the fingers and binding, the impression of the rifling of the binding is reproduced on the skin of the fingers for, as has been stated, the outer as well as the inner surface of the whipcord cylinder is rifled. The rifling formed by the whipcord acts as a rudimentary mechanical extension of the human riflings which are formed by the spaces between the fingers and creases at the insides of the finger joints. The mechanical rifling is very regular and geometrical in shape, and is a very imperfect form of the human riflings; and the human riflings and mechanical riflings do not fit each other.

The rifling on the surface of the binding is near the human riflings; and is transferred immediately from the human riflings (Rule 7). The rifling on the outer surface of the binding is also transferred to the inner surface of the binding, that is from one side of the binding to the opposite side (Rule 8). If gum is used to help to fasten the whipcord to the shaft, the shaft may show signs of rifling, through the gum being forced up into the spiral between the turns of the whipcord. Rifling impressions are then transferred to the surface of the shaft, with which the rifled cylindrical barrel is in contact (Rule 7).

If the barrel formed by the fingers could be removed from the binding without altering its shape, and next the cylindrical whipcord barrel could be removed from the shaft, it could be seen that the form of the shaft is reproduced by the interior of the cylindrical barrel formed by the whipcord, and that the form of the exterior of this barrel is reproduced

by the interior of the human barrel; and it could be seen also that the human barrel fits and encloses and holds the barrel formed by the binding, and that this inner barrel in turn fits and encloses and holds the shaft. The human barrel and mechanical barrel are clearly complementary in forms, and together form a barrel for the shaft.

The breech is formed by the palm, and since the shaft and binding lie partly in the palm, they lie partly in the breech. The breech is rifled, for the binding impresses its shape on the palm, and the skin is pressed into the spiral between the turns of the whipcord.

The ancient athletic javelin was spun by the help of its binding which unwound as the javelin was being thrown. The binding consisted of a thong which was wound a few times round the shaft. A loop was left for the insertion of the forefinger or first two fingers. As the javelin was being thrown, the thong unwound and imparted a rotary motion to the javelin causing it to spin in flight. The device was called the amentum by the Romans, and the ἀγκυλη by the Greeks. Authorities differ as to whether the amentum was fastened to the shaft and thrown with it, or was retained in the hand.

The loop of the amentum formed a mechanical extension for the forefinger or fingers, and by its help the spinning actions of the forefinger or fingers were magnified and continued for a few moments after the shaft had left the hand.* As the thong unwound, the spiral between the turns of the thong decreased in length, and as it decreased the missile spun more quickly. The rate of spinning was therefore related to the length of the spiral at any moment. The spinning mechanism was partly human and partly artificial.

The modern binding is very regularly rifled; but the rifling device is of little use in helping to spin the missile, and the modern binding seems to be an atrophied spinning device. It may afford some help indirectly in spinning the javelin by allowing the fingers to obtain a good grip, for as the

* According to E. N. Gardiner, "The action of the amentum is similar to that of the rifling of a gun."

javelin leaves the hand a small measure of spin is imparted to it.

The ancient amentum conversely was very irregularly rifled by the turns between the thong wound round the shaft. Conversely also as has been explained, it was of much help in spinning the missile. This helps to show that a regularly and geometrically shaped device is not necessarily a better device than one less regularly and geometrically shaped, and that regular mechanical riflings are also not necessarily superior to their irregular human prototypes.

The spinning action is not performed solely by the fingers. The wielding arm also takes part in the action.* But the spinning mechanisms of the fingers and arm are very little mechanized by means of the modern binding, and are difficult to study and analyse from direct observations of the javelin throwing machine.

That the throwing-arm of the wielder of a weapon plays a part in imparting spin to the missile is brought into prominence when the chakra, or war quoit of the Sikhs of India is wielded, for it is twirled by the forefinger before being thrown and the arm takes part in this movement. The chakra is a thin, circular ring of metal sharpened to a razor-like edge on the outside. Several are worn on the arm or on the turban, and can be thrown in quick succession from the forefinger. The chakra is twirled horizontally, with the forefinger held higher than the head. It is said it can inflict serious wounds and may even sever a limb. Since the Sikh obviously spins his chakra by means of movements of his arm as well as forefinger, it can be known, since the principles of all types of the offensive machine are the same, that in all types of the machine, including the javelin machine, the spinning movements are primarily performed not only by the forefinger or fingers but also by the wielding arm.

The Caber

The missile of the caber tosser is the trunk of a tree. It

* According to F. A. M. Webster, we should "observe the rotation of the throwing arm from left to right to give the spear a rifling spin."—*Athletics of To-day*.

is so heavy that the tosser needs the help of assistants to bring it into an upright position with its small end resting on the ground. When it has been brought into an upright position the assistants retire and the tosser places his shoulder against it and cautiously raises it so that he can place his hands underneath its end. When he has placed the end in the pouch made by his hands, he raises the caber and carefully balancing it begins to run forward. At the right moment he gives an upward heave with his hands and tosses the caber which should turn over in the air and come down with its big end on the ground and fall with its small end pointing away from the tosser.[1]

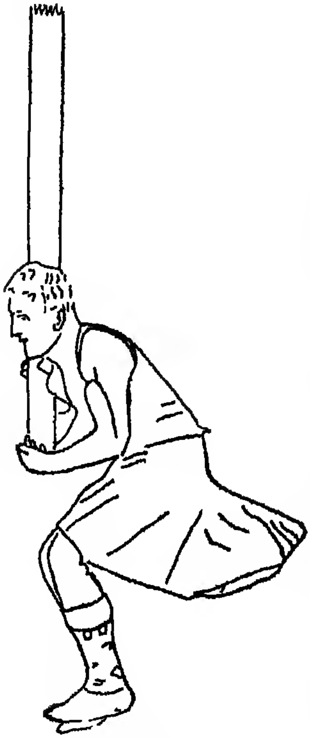


FIG 23.
BALANCING THE CABER
By courtesy of Aberdeen Bon-Accord and Northern Pictorial

The end of the caber fits into a human breech and back part of a barrel formed by the hands and fingers. The breech is formed by the palms, and back parts of the barrel by the parts of the fingers which surround and press against the cylindrical surface of the caber. Because of pressure between the caber and hands and fingers, the shape of the caber's end is automatically and faithfully reproduced on the palms and insides of the fingers; and the caber fits closely into the human breech and back parts of the barrel.

Parts or bits of a cylinder are therefore reproduced by the insides of the fingers in contact with the cylindrical surface

[1] W. M. Smith, F.S.A., Scot., *The Athletes and Athletic Sports of Scotland.*

of the caber. The diameter of the cylinder partly formed by the fingers is of course the same as the diameter of the end of the caber, that is the bore of the back part of the barrel is equal to the diameter of the lower end of the caber.

The human breech and the barrel partly formed by the fingers cannot by themselves hold the caber; but control is obtained because a fore part of the barrel is formed by the shoulder. The pressure of the caber on the shoulder causes the skin and flesh of the shoulder to be deformed to the shape of the caber, and a slight groove having the shape of part of the surface of a vertical cylinder is formed in the shoulder. Since the surface of the caber is continuous, the groove in the shoulder is part of the cylinder partly formed lower down by the fingers.

The part of the barrel at the shoulder and the parts at the lower end of the caber do not meet, and are separated by the distance between the shoulder and the hands. In the gun machine, the barrel is continuously formed and is not in separate parts as in the caber machine. Mechanization allows a continuous barrel to be formed, and also allows it to be made of a simple shape; and the gun barrel is a continuous tube of nearly uniform diameter.

The barrel of the caber machine is slightly mechanized when a cloth is placed against the shoulder, *Figure 23*. Sometimes, to prevent the caber hurting the shoulder and to obtain better control over it, a cloth is placed against the shoulder for the caber to rest against. As the caber presses against the cloth, its shape is impressed on it, and rather less distinctly on the shoulder also. A deeper and wider groove or barrel is formed in the cloth than in the shoulder when no cloth is used. Since the cloth is not a part of the body and is an artificial contrivance, the barrel is partly artificial or mechanical at the shoulder when a cloth is used.

The length of the barrel, although it is not continuously formed, is equal to the distance between the shoulder and the fingers. It varies according to the dimensions of the tossers and their methods of holding the caber, but is usually about two feet in length. The missile, which is the caber,

therefore is not contained wholly within the barrel, but projects several feet beyond its limits.

The diameters of the two parts of the barrel are not quite the same, since the caber is of greater girth near the shoulder than at the hands; that is, the barrel of the caber machine, like that of most gun machines, is not of uniform bore along its length. If the diameter of the part of the caber at the fingers is say three inches, the bore of the barrel there is three inches. Since the girth of the caber increases away from the hands, the bore at the shoulder will be rather more than three inches. Often the caber at the hands has a girth of much more than three inches.

The caber machine is remarkable for the great length and bulk of its missile. It has a longer missile than any gun machine, for no gun has a shell of say twenty feet in length. Its bulk is also greater than that of most missiles fired from guns. The calibre of the caber machine may exceed that of a six inch gun, but an eighteen inch gun, for example, has a larger calibre than the caber machine, for the diameter of a caber is never as great as eighteen inches. Thus, with a very slight degree of mechanization the offensive machine can be distorted so that its missile is longer than the missile of any gun machine, and so that the calibre of its barrel is exceeded only by the calibres of large and heavy gun machines.

During the run forward the hands hold the caber at the right height above the ground, and the hands and shoulder, or hands and cloth and shoulder, act together to keep it in a vertical position. When the tosser begins to throw the caber, the part against the shoulder begins to fall away from it, in a direction at right angles to the axis of the caber. The missile is therefore propelled not along the axis of the part of the barrel at the shoulder but in a direction at right angles to it; and the missile is not propelled after the manner of a shell or bullet, in a direction along the axis of the barrel but at right angles to the barrel. The direction of motion of the missile, compared with that of a shell, is therefore turned through a right angle, in accordance with Rule 10.

The caber can move away from the barrel at the shoulder in a direction at right angles to it, because the barrel there does not surround it. If the barrel surrounded the caber, the caber could fall away from the shoulder only by first breaking the barrel. A complete cylinder to surround the caber could perhaps be devised, say by using straps to hold it to the shoulder; but the missile would then have to be propelled through the barrel formed by the straps and shoulder, along the axis of the barrel, or the straps would have to be suddenly undone to allow the caber to fall away from the shoulder, and difficulties would probably be experienced in releasing the straps quickly enough.

As the caber is being tossed, a powerful upward heave is given by the hands, which is compounded of two movements, one a thrust along the axis of the caber to throw it into the air, and the other a thrust at right angles to its axis to make it turn over, or spin, about its centre of gravity so that it will land on its large end and fall forward with its small end pointing away from the tosser. Since a thrust is given along the axis and at right angles to it, the small end therefore, like the part at the shoulder, has a movement at right angles to the barrel.

The thrust along the caber's axis is directly given by the back part of the human breech, that is by the parts of the hands under the end of the caber, which are the human prototype of the breech block or breech face of the gun. The breech face of a gun similarly gives the thrust which sends the shell forward, for the exploding charge presses against it to obtain its power to drive the shell from the barrel.

It may be remarked that the gun's barrel and breech have not been developed directly from those of the caber machine, which is little more than an exhibition machine which however illustrates many principles obscured when many other varieties of the offensive machine are in action. As will become apparent later, the barrel and breech of the gun have been developed directly from those of the bow and arrow machine. These devices of the gun machine are however related to those of the caber machine.

The rifling devices of the caber machine are not mechanized. They are formed by the grooves between the fingers and by the creases across the insides of the finger joints. Since they are human, it is difficult and perhaps not possible to know much about them, except in a general way, by direct observation of the machine.

It can be known that rifling devices are formed for the caber machine, without even troubling to examine the machine; because if any part or device of the offensive machine is not mechanized, the wielder's body automatically forms and supplies it. No part or device can be omitted, otherwise the machine cannot work properly. Rifling devices must be used when the caber machine is in action, or the caber could not be turned over, or spun. Since there is no binding round the caber or feathering as on arrows, or any other similar type of device that might help to form a rifling device, it can be known at once that the rifling devices are supplied by the caber tosser's body. Human rifling devices, of course, as has been pointed out, are formed by the spaces between the fingers and by the twelve creases across the insides of the finger joints. Again, every machine must have a stock, butt, trigger, trigger spring, elevating and depressing devices for obtaining aim, and a thousand and one other parts and devices; but none of these parts or devices are mechanized in the caber machine, and therefore the caber tosser's body must form and supply them.

The recoil of the caber machine is powerful, and movements must be made by the tosser to prevent himself being tossed by the caber. None of the recoil mechanisms are mechanized, and all are supplied by the wielder's body.

A bullet or shell or arrow spins about its axis, but the caber spins in a plane which includes its axis. The axis about which a caber spins is therefore turned through a right angle compared with the axis about which a bullet, shell, or arrow spins, in accordance with Rule 10.

As a result of fitting such a large and heavy missile to the body without at the same time mechanizing any of the machinery that tosses it, the movements of the wielder are

slowed down so much that the way the power is delivered can fairly easily be studied, in a general way. The throwing movements are slowed down so much that at least six stages of the movements can be easily observed. The first stage of the movements is the placing of the foot against the smaller end of the caber while the assistants raise it into a vertical position; the second, the placing of the hands underneath the smaller end and the raising of the caber; the third, the pause while the caber is being steadied and the thrower is obtaining his direction; the fourth, the run forward; the fifth, the throwing of the missile and the upward heave to make it turn over in the air; the sixth, the balancing movements made necessary by the recoil. When the shot is being wielded, the throwing movements are slowed down sufficiently for most of these stages to be observed. The fourth stage, or the run forward, is represented by the steps and hops made by the shot putter. Some of the stages can be well seen when the cricket bowler is in action, the fourth stage being seen in the run made by the bowler. The stages can also be observed when the javelin is being wielded. They cannot be observed easily when the fist is being wielded, for the hitting actions take place too quickly. The spinning of the missile can be very clearly seen when the caber tosser is in action, the caber being made to turn over, or spin, in the air by the upward heave given by the hands at the final moment. As has been stated, however, the parts of the body which spin the caber or perform the throwing and other movements are not mechanized, and so, although they can be observed in a general way, exact information about them or their actions cannot be obtained from observations of the actions and movements of the caber tosser.

The Discus

The discus at the beginning of the movements of the discus thrower is held against the palm and wrist of the right hand, with its rim in the top joints of the fingers which are curled over its edge. The left hand is placed against the side of the discus opposite to the right hand, to prevent it falling.

During the whirling movements, the discus is directly held only by the right hand, and use is made of centrifugal force to retain it in the hand.

The discus therefore rests in the breech of the right hand, which is formed by the palm, and also in the barrel of the right hand, which is formed by the fingers. At the beginning of the movements, the discus is also in the barrel of the left hand, formed by the fingers pressing against it to hold it to the right hand. As the left hand is removed from the discus, the parts of the barrel become separated; and the discus machine therefore has an extensible barrel. The length of the barrel measured from the left hand fingers to the right hand fingers, is at a minimum when both hands hold the discus, and at a maximum probably when the discus is being released.

The human barrel of the right hand is not continuously formed, but is formed in a fragmentary way by the parts of the right hand fingers at the rim, the fingers being separated by different distances. The diameter of the barrel is the same as, or very slightly greater than, the diameter of the discus. The modern discus is 8⅝ inches in diameter; and therefore the modern discus machine has a barrel of greater diameter than an eight inch gun machine. The diameter of the ancient Greek discus was usually between 6½ and 9 inches; but one extant specimen has a diameter of over 13 inches; and the bore of the barrel of the discus machine can therefore be greater than that of a thirteen inch gun machine. It is not certain, however, that this particular specimen was actually used, and it is thought it was perhaps a votive offering.[2] The length of the missile of the discus machine is very small, and is equal to the thickness of the discus.

The rim of the discus rests in the bits of grooves formed by the creases across the insides of the top joints of the right hand fingers, and thus fits into the rifling of the human barrel which is formed by these fragments of grooves, in much the same way as the driving band of a bullet or shell fits into

[2] E. Norman Gardiner, M.A., *Greek Athletic Sports and Festivals.*

the grooves of the gun barrel; and the mechanical and human devices work together to spin the discus.

THE HIGH JUMPER

The high jump machine has no mechanical parts, provided the jumper does not wear shoes or vest or trousers; and therefore little can be learnt about its actions until after a study of mechanized missile throwing machines. But a few facts can be noticed, in a general way.

The missile is the entire body. It may be thrown at an opponent, as for example when a person jumps or hurls himself at an opponent. The body is not often used in this way, and is so used usually only in an emergency. In an athletic competition the missile, or body, is thrown at a target representing the opponent or opponents.

Vests and trousers are not strictly parts of the offensive machinery, although they become part of the missile when worn. A study of clothing, by means of the human prototype theory, would show they are extensions of the clothing machinery of the body. Shoes are important, although not necessary parts of the machine; and by means of them the machine is slightly mechanized. A fuller discussion of shoes, showing how they are related to and work in harmony with the feet will be given later, and it will be necessary here to notice merely the part played by the sole of the shoe.

The sole of the shoe lies under and covers the sole of the foot. It is therefore a mechanical reproduction and extension of the skin of the sole of the foot (Rules 1 & 3). Correspondence of shapes is fairly close. Indeed a shoemaker will often trace the outline of a person's sole, for whom he is making a shoe, on a piece of paper by drawing round it with a pencil, so that he can ensure good correspondence of size and shape of the shoe to the size and shape of the sole of the foot. If the sole is of leather correspondence of materials also is close, for leather is the skin of an animal, and the skin of an animal closely corresponds in structure to the structure of the human skin, although certain features of the

animal's skin are destroyed or spoiled when it is made into leather.

From the beginnings of civilization it has been the practice to protect the skin of the sole of the foot by giving it an artificial extension by covering it with the skin of an animal. By the use of skin or leather many of the features of the human sole can easily and effectively be reproduced. But dead skin or leather differs from the skin of the sole of the foot, and the skin of an animal also is not exactly similar to the skin of the human sole. Therefore this method of giving the human sole an extension can never be quite satisfactory. Attempts have been made in recent years to use other materials, and especially rubber. A sole of rubber can reproduce several of the features of the human sole. It can also reproduce some of the features of the flesh of the foot that lies underneath the sole, notably its elasticity and shock absorbing properties. This substitution of a synthetic or manufactured material for a natural material for making parts illustrates a common occurrence in the process of developing the offensive machine; and represents an attempt to copy parts of the machine less directly and therefore usually more effectively. A notable example of the use of a synthetic or manufactured material instead of a natural material is given when say a sword is made of metal instead of wood. However synthetic materials like rubber or metals do not reproduce as many of the features of skin and flesh and bone and other constituents of the body as are reproduced by skin, thongs, wood, and similar natural materials; and when they are used it always becomes necessary to try and reproduce by some other means some of the features and properties that cannot be reproduced by the synthetic materials.

A main purpose of the sole of the shoe is to protect the skin of the wearer's sole from abrasion by the ground. But it may be of some small assistance in the jumping actions, for the jumper's height is increased, by an amount equal to the thickness of the sole of the shoe. The shoe takes part in all the actions of the sole of the foot (Rule 4), and cannot

have independent actions, and becomes part of the missile and is thrown with the body at the target.

The sole of a shoe is related, as will be explained later, to the heel-plate of a rifle or shot gun, which therefore like the sole of the shoe has the skin of the sole of the foot as its human prototype.

The main parts and devices of the machine are formed by the body. The barrel, riflings, sights, stock, butt, breech, and many other parts and devices can be seen, but little can be learnt about them by observation of this machine alone. Rifling devices can be seen as the high jumper clenches or partly clenches his hands when about to jump, formed of course by the spaces between the fingers, and creases across the insides of the finger joints. The stock of the machine is formed by the stock of the body, but its construction and methods of working cannot be easily observed. The butt is formed sometimes by one leg, sometimes by the other, and sometimes by both legs; but it cannot easily be studied directly.

The Long Jumper

The missile of the long jumper is his own body. The fists of the long jumper are sometimes partly mechanized by means of jumping-weights, in shapes something like dumb-bells, which are held in the hands in order to obtain more momentum for the jump. They are retained in the hands during the jump and become part of the missile.

Some jumping-weights have grooves for the fingers, each finger having its own groove. Mechanical riflings are then formed by the grooves of the weights. The ridges between the grooves of the weights fill the grooves or spaces between the fingers, and are complementary to them. Faults in making or designing the grooves are remedied to some extent by the fingers forcing the skin and flesh into the grooves and taking their shapes.

An ancient Greek jumping-weight is shown in *Figure 24.* It is of stone and seven and a half inches long. Its rifling

devices are well developed mechanically, and can be very clearly seen. The four fingers in *Figure 24* fit into four grooves. The stone ridges between the fingers correspond to the "lands" or parts of the interior of a gun barrel which are not cut away when the rifled grooves are made. The ridges between the middle and third fingers and between the third and little fingers are somewhat similar in shapes; but the ridge or "land" between the forefinger and middle finger is wider than the other two lands, and less regular in shape. The stone where it is incised is approximately in

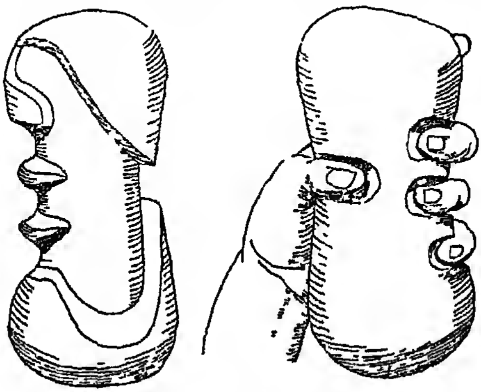


FIG. 24. STONE JUMPING-WEIGHT
British Museum Guide Book

the form of a cylinder, and therefore the barrel formed by the hand is approximately cylindrical. The breech for the stone is formed by the palm of the hand. The jumping-weight therefore rests in the breech as well as in the barrel of the hand. The jumping-weight is not thrown but is retained in the hand, and therefore has no movement relative to its barrel and breech during the propelling of the missile, which is formed by the whole body and the two jumping-weights.

The mechanical rifling devices formed by the grooves and lands of the jumping-weight are much better mechanical counterparts of the rifling devices of the hand and fingers than are the grooves and lands of a rifle or other gun. The

designer of the Greek jumping-weight has noticed how the fingers lie around a cylindrical stone, and has cut grooves for the fingers and palm to sink into; and the devices he has made can readily be recognized as complementary to devices made by the fingers and palm as they hold the stone. The designer of a rifled gun, however, makes grooves of more or less regular and simple geometrical patterns, which cannot directly be recognized as corresponding to devices formed by the wielder's hands; and it is only after a study of many types of weapons that it becomes evident that the rifling devices on gun barrels are related to and derived from the rifling devices of the hands.

But although the riflings on the jumping-weight are in an advanced stage of mechanical development and those on a gun are in a primitive stage of mechanical development, the gun maker has the advantage that the riflings on a gun barrel are in forms which permit of further mechanical development, but those on the jumping-weight cannot be much further developed mechanically. The Greek designer has been too ambitious, and has tried to copy nature too directly. He has tried to reproduce counterparts for all the human rifling devices: the gun designer has been content to reproduce only a very few of the characteristics of the human riflings, and those only in the simplest possible ways.

Attempts are continually being made by makers of weapons to copy nature's devices directly. Many things can be learnt by trying to do so; but nature's mechanisms are much too complex to be copied directly. In early times, for example, makers of weapons tried to reproduce all the features of the fist by placing a roundish stone in the hand for use as a club or missile. But only certain characteristics of the fist like its roundness, hardness, size, and weight, can be reproduced in this way; and no useful offensive purpose would be served by trying to make the stone correspond more closely outwardly to the fist, say by fashioning it to possess knuckles and joints and finger nails. The archer has discovered it is better not to try and reproduce the whole of the fist at once, but to be content with reproducing merely a knuckle

of the fist, in the form of the head of the arrow, and to be content also with reproducing only a very few of the characteristics of the knuckle. This will be more fully explained later, in the chapters on the bow and arrow.

The grooves and lands on the stone jumping-weight shown in *Figure 24* are derived immediately from the rifling devices of the fingers, for when the stone is held the human and mechanical devices are in contact (Rule 7). The mechanical devices are reversed or inverted compared with the human devices, because where there are grooves between the fingers there are ridges or lands on the stone, and where there are ridges or lands formed by the fingers there are grooves in the stone.

The jumping-weight is pitted all over its surface with tool marks. These markings are not shown in the sketch. Unconsciously and unintentionally perhaps the maker has therefore reproduced mechanical counterparts for the chequerings which are formed by the creases and fine lines on the surface of the skin of the hands and fingers. Certain parts of the hand and fingers are in contact with the markings cut in the surface of the stone, and therefore by Rules 1, 3, & 7 the mechanical markings act as mechanical extensions of the human chequerings. They are indeed of much assistance in helping the hand and fingers to obtain a good grip. No doubt the maker could have smoothed out the tool marks, but perhaps he saw that it was better to leave the stone "rough", to allow the skin to sink into the indentations and the projections to sink into the skin. He has made no attempt to make the tool marks, or mechanical chequerings, in the reverse pattern of the human chequerings, so that the mechanical and human chequerings could fit into each other.

Since no attempt has been made to reproduce the actual pattern of the human chequerings, it is not possible to know from direct observations that the tool marks are mechanical extensions of the human chequerings. This can be known only by seeing that when the stone is held the tool marks lie against the human chequerings, that they help the hand to

make a good grip, that they are lightly cut in the surface of the stone, that types of criss-cross markings are formed, and that during the wielding movements the human and mechanical markings move together and cannot have different movements. The reader will see that by the application of the Rules, the fact that the tool markings form artificial extensions for the human chequerings can be established beyond doubt.

The sketch does not show clearly if the grooves in which the middle, third, and little fingers lie are spiralled. But a photograph supplied by the British Museum makes it fairly clear that neither of the three lower grooves if continued round the stone would return to its own groove. The three grooves seem to have the same pitch.

The grooves for the middle, third, and little fingers are approximately parallel, and run round the stone in planes almost at right angles to the axis of the cylindrical part of the stone. The grooves on a gun barrel, however, run nearly parallel to the axis of the barrel. It seems therefore that the general direction of the riflings on a gun barrel compared with the general direction of the riflings on a jumping-weight is turned through a right angle (Rule 10).

The groove for the forefinger is at a different pitch from the others, and is much more steeply spiralled. The pitches of the riflings on this jumping-weight are therefore not all the same. The pitches of the riflings on the interior of a gun barrel are of course equal to each other, that is, all make the same number of turns along the length of the barrel, and no gun barrel has been made having the pitch of one of its grooves at a different angle from the others.

The cylindrical part of the stone has lands and grooves on its surface. The human barrel formed by the fingers therefore encloses a rifled cylinder. The human barrel itself is rifled internally, but the enclosed cylinder is rifled externally. A bullet or shell is somewhat similarly a cylindrical object enclosed within a barrel. The gun barrel is rifled internally, and the bullet or shell becomes rifled externally

as it is propelled through the barrel, because the leaden bullet or the driving band of the shell is forced into the rifled grooves of the barrel. The ridges on the stone cylinder may therefore be compared to the ridges formed on a bullet or shell which fits into the grooves of the gun barrel. The spaces between the fingers correspond to the grooves in the gun barrel, and the devices made by the fingers correspond to the lands in the gun barrel.

The stone jumping-weight has a separate groove for the thumb; and therefore has five grooves altogether. The author is not able to say if the thumb groove is a rifling device. Rifling devices are essentially spinning devices; and the human rifling devices are operated sometimes, as for example when a cricket ball is spun by the bowler, when a coin is spun, when a marble is shot from the foreknuckle by the nail of the thumb, or when a bowl is sent towards the jack; and are operated in conjunction with mechanical extensions of the fingers as when a top is spun with a string or a javelin is spun with an amentum, the string being a mechanical extension of the forefinger device. The cricket bowler perhaps could spin the ball without the help of the thumb, and a boy might be able to spin a top without the help of his thumb. The thumb however is certainly of use in the spinning actions, but its essential purpose is perhaps to act as a clasp to secure the missile or weapon to the hand.

The jumping-weight is held to the four fingers partly by the pressure of the thumb on the stone. The thumb forms a clasp to connect the stone to the hand, and the four fingers also form clasps; and each of the human clasps works in co-operation with the others. One reason why the forefinger is made to diverge from the others is evidently so that it can exert leverage on the stone. The fork of the thumb forms a catch to prevent the stone moving up the hand against which it is pressed by the fingers. The stone lands help to form the clasps, because they prevent movement of the stone up or down the hand. The tool markings also help to hold the stone to the hand and fingers by providing indentations for the skin and flesh to sink into and projections to press

into the skin. But it is difficult to distinguish the rifling, chequering, and clasp devices.

Trigger and trigger spring mechanisms are formed by the fingers. Strong trigger springs must be formed to enable the fingers to clasp the stone firmly. The trigger spring is opened to receive the stone and then closed. The stone is not thrown, and the trigger is not set free during the jumping movements.

Figure 25 shows an engraved votive discus of the sixth or fifth century before Christ, representing a Greek athlete with halteres, or jumping-weights, preparing to jump. The discus is 8¼ inches in diameter and weighs rather more than 4 lb.

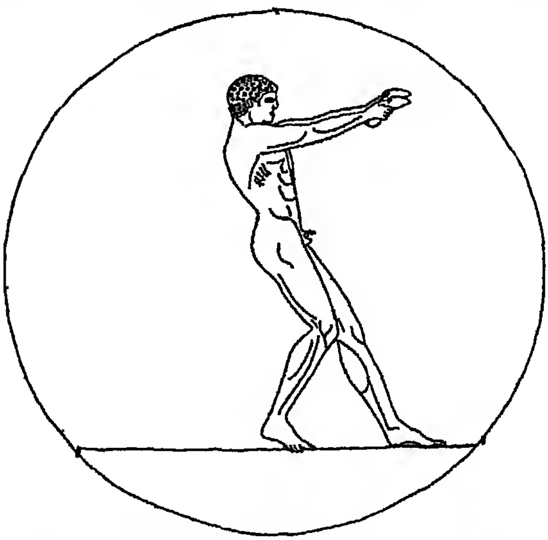


FIG. 25. ATHLETE PREPARING TO JUMP
British Museum Guide Book

On the reverse side, which is not shown here, is a representation of an athlete holding a javelin in his hands and apparently about to throw it.

THE POLE VAULTER

The weapon of the pole vaulter is somewhat similar to that of the javelin thrower or wielder of a thrusting spear.

It usually has a sharp iron or steel point, so that it will stick in the ground, and is indeed a type of spear; but it is not used directly against an opponent or target as the javelin or spear is used, but is used to throw the body, or missile. The javelin forms the missile of the javelin thrower, but the body forms the missile of the pole vaulter, and the pole is used only as part of the machinery which wields the body and throws it. When the javelin is thrown the body remains at about the throwing point; but when the body of the pole vaulter is thrown the pole remains at about the throwing point. The pole vault is therefore in many respects the reverse of the javelin throw.

The barrel of the pole vaulting machine is formed in somewhat the same way as the barrel of the thrusting spear machine. Riflings and other devices are formed only by the body.

The Hammer and Weight

The hammer of the hammer throwing machine consists nowadays of a heavy ball to which a steel wire with a stirrup, or stirrups, for the hands is fastened. According to Olympic Games' regulations the weight of the apparatus must be not less than 16 lbs., and the length not more than 4 feet. The modern hammer is thrown from a circle of 7 feet diameter, and in order to obtain momentum for the throw, the thrower turns round two or three or more times before throwing the hammer.

Both hands are used to wield the hammer. When two stirrups are provided, one is usually a little longer than the other and is held by the left hand. When only one stirrup is provided one hand is placed on the stirrup bar and the other is placed over it. The barrel is in two parts when two stirrups are used, one part being formed by the insides of the fingers of one hand as they curl round the bar of one stirrup, and another part by the fingers of the other hand placed round the other stirrup. The two parts are parallel and side by side when the thumbs and middle joints of the fingers of each fist face and touch each other. The thumbs

and middle joints of the fingers of each fist form a fairly flat surface, and when the two surfaces are close together a kind of very large fist is made by the two fists together, to which the ball of the hammer bears some remote resemblances in size and shape; and the ball is probably a mechanical extension of the combined fists transferred to the other end of the wire or shaft. When one stirrup only is provided, a kind of fist is made by the hands as one is placed over the other.

The stirrup does not lie in the breech of the hand, for the breech of the hand, that is the device formed by the palm, is at some distance from the bar of the stirrup.

To prevent the hands being hurt by the stirrup or stirrups, sometimes stout leather gloves are worn. The barrel is then partly mechanized by means of the parts of the gloves in contact with the stirrup or stirrups, the parts of the glove in contact with the bar or bars forming a kind of artificial skin for the fingers.

The fastenings which hold the bar or bars to the hands are human and formed by the fingers which form clasps as they curl round the bar or bars. The fastenings are partly mechanized when gloves are worn, for parts of the glove then become parts of the clasp devices. The hammer is released by the finger clasps being made to relax and straighten. The clasps are of much the same types as those formed by the ends of the strings of slings, which will be discussed in the chapter on the sling.

Power is generated by rapid turns of the body, the hammer being swung around the body and use being made of centrifugal force.

To prevent the wire twisting, the head of the hammer is fastened to it by means of a swivel, which is a crude mechanical reproduction of the elbow or wrist joint. The swivel allows the head to turn, or spin, relatively to the wire and arms. The stirrups and wire and head cannot be separated and are thrown together.

When the hammer has a stiff shaft, rigid parts of the wielding arms are given extensions. But when the shaft is of flexible cane, flexible components of the arms are also

mechanized. The steel wire serves perhaps as a mechanical extension for the rigid and flexible components of the wielding arms, for although the wire is of hard materials it is also flexible. According to F. A. M. Webster "in the actual turning, and before the final heave is reached, the arms act merely as a rope between the handles of the hammer and the body;"[3] and it is evident therefore that the wire acts as an extension of this "rope". The complete rope, of course, is formed by the arms and by the wire, and is partly human and partly artificial. The rope formed by the arms is presumably formed by components like sinews, tendons, and muscles, but exactly how the human components form the rope is difficult to determine merely from observation of the hammer throwing machine. But some information about the "rope" can be obtained after a study of the strings or cords or ropes of weapons like slings, bows, and trebuchets.

The weight resembles the hammer, but it is heavier and there is no swivel or wire, but perhaps the wire is represented by the link. According to Olympic Games' regulations the weight of the apparatus must be not less than 56 lbs., and the length not more than 16 inches.

The weight is too heavy to be a mechanical reproduction of the fists, even allowing for much distortion. Possibly it is a mechanical reproduction of the stock or of part of the stock of the body, but this cannot be definitely stated. Barrel and rifling devices are formed much as in the hammer throwing machine.

The recoil of the weight slinging machine is powerful; and care must be taken by the slinger to prevent himself being thrown by the weight. The recoil machinery is not mechanized. The weight is probably a modern form of the boulder or mass of metal thrown by the ancient Greeks.

[3] *Success in Athletics.*

CHAPTER 20

GENERAL OBSERVATIONS

THE fist can be mechanized by fitting a roundish stone to the hand, the claws by fitting a baghnak to the fingers. The stone can be recognized as a crude mechanical derivative of the fist because it has a remote resemblance to a fist, it is held in the partly clenched fist, it partakes of the actions of the fist, it cannot have actions different from those of the fist, and so on. The baghnak can be more readily recognized as a mechanical derivative of the human claws, because resemblance of the baghnak to the human claws is closer than resemblance of the stone to the fist.

Particular parts of the fist can be mechanized by means of the caestus or the knuckleduster or the gauntlet. The points or ridges of the knuckleduster are mechanical extensions of the knuckles over which they lie. The ring, or main part, of the Greek caestus is also a mechanical extension of the main knuckles.

After some study of mechanical weapons, it becomes apparent that a mechanical part, unless in a transferred position, is always close to its human counterpart. The human counterpart of a part of a weapon can therefore usually be known simply by noticing the part of the body holding it or in contact with it.

According to Rule 3, a mechanical part originates as an extension of a human part. Thus, one type of the mechanical fist originated as a stone held in the hand to club an opponent; types of mechanical knuckles as the ring or bar of a caestus; types of mechanical claws as the claws of a baghnak; and so on. Always the mechanical device emerges from its human counterpart, and forms an extension for it, and is a crude copy of it. A mechanical part therefore emerges from the offensive machine as a kind of growth; and probably the

processes by which mechanical weapons originate and develop are similar to the processes of growth of plants and creatures. Therefore when a study is made of the ways in which weapons, or other mechanical contrivances originate and develop, some knowledge is obtained of the ways in which plants and creatures grow.

A mechanical weapon becomes an integral part of the offensive machine when it is fitted to the body, and enters into organic relationships with it. This is evident also because the parts of the weapon are arranged in the same ways as their human counterparts, necessarily because each is an extension of its human counterpart. The weapon partakes of the life of the machine, and life is organized in the weapon as in the human counterparts, but more crudely because of imperfections and distortions of the mechanical parts. The property of life is given to the mechanical parts by the human parts, and they do not possess any life of their own. The weapon possesses no life when it is disconnected from the body. It is then merely a collection of pieces of materials. A leaf similarly, for example, possesses no life when disconnected from the tree, and becomes then merely a collection of pieces of materials.

To mechanize the knuckles by means of a caestus requires also the partial mechanization of the skin of the hand and wrist and forearm and fastenings which hold the fist to the forearm. To mechanize any part of the fist by means of a caestus therefore requires means to be devised of mechanizing various parts and devices of the wrist and arm.

The fist and hard parts of the arm can be mechanized by means of the club. The handle is a mechanical extension or derivative of the wielding arm which extends along its length outwards, and the head is a mechanical extension or derivative of the fist transferred to the end of the handle opposite its human counterpart. As a result of transferring the mechanical part of the fist, it becomes easy to distort it, and it is often distorted so much that it often has little resemblance to a fist. Also, the heads of some clubs are not mechanical reproductions of the fist, but are mechanical

reproductions of the weapon formed by the open hand, as is evident often from their shapes and methods of wielding them. Some heads are perhaps mechanical reproductions of the shoulder blade.

By transferring a device somewhat resembling a baghnak to the end of a handle, a rake can be made and the wielding arms and claws can thus be mechanized. But a rake type of implement is seldom used as a weapon, but finds much use as a tool for gardening. The beak of a halberd however is a type of claw transferred to the end of a mechanical extension of the arms.

By mechanizing a part of the offensive machine, the actions of that part can be magnified and extended, often to a very great degree. Parts can sometimes be easily magnified in size, weight, hardness, or sharpness, by simple types of extensions. Thus, *the thrusting actions of the fingers, which* are small, can be considerably increased simply by fitting a pointed stick to the hand and using the point instead of the fingers. By hardening the point of the stick in the fire, they can again be increased. By making the point of iron or steel, they can be increased very greatly, so much so that it may be difficult to relate the thrusting powers of the fingers to those of the weapon. The smashing powers of the fist are small: they can however easily be increased by mechanizing the fist simply by placing a roundish stone in it. By mechanizing the wielding arm and fist by means of a wooden club, much harder and heavier blows can be given than can be given by the unmechanized fist. By making the head of the club of iron, a sledge hammer can be made, and the fists be given very hard and heavy extensions. When a caber is fitted to the body, the barrel of the offensive machine is greatly increased in calibre, and the missile or hitting part is very greatly increased in length and bulk.

The cutting and slashing powers of the sides of the hand and arm are small. They can be somewhat increased by means of a wooden sword. By means of a metal sword, and especially a steel sword, the powers can be greatly increased.

A stone can be thrown, or transferred to the end of the

trajectory. Similarly a club or sword or almost any hand weapon not bound to the hand can be transferred to the end of the trajectory. When a roundish stone is thrown the artificial part of the fist goes forward to deliver the blow, but the human part remains behind. When a club is thrown, artificial parts of the fist and arm go forward, but their human counterparts remain behind. The parts of the machine which are thrown, however, remain connected to the machine by the link of the trajectory, at least until transference is completed. When the whole body is thrown, the entire machine is transferred along the trajectory to its opposite end, as for example, when the body is thrown in the long jump.

When any human part is mechanized it is partly relieved of the task of directly carrying out offensive actions, although of course it must operate the mechanical part. Thus, when a roundish stone is held in the hand to club an opponent, the hand need not come into actual contact with him and directly deliver the blow. But indirectly and primarily the hand gives the blow, and comes into contact with the opponent through the agency of the stone.

The degree to which a human part is relieved of the need for directly carrying out offensive actions depends upon the degree of mechanization and is perhaps proportional to it. Thus, the fist is very little mechanized by means of a roundish stone, and must therefore go through the motions of clubbing the opponent, and the fitting of a stone cannot relieve it of this task. When a club is being wielded, the fist at the grip and the wielding arm must go through the motions of clubbing the opponent. When a shot is putted, although the shot alone goes all the way to the opponent along the trajectory, the hand and fingers go part of the way along the trajectory, and remain extended along it for some time after the shot has left the hand, this action being seen in the "follow through" movement. When the javelin is being thrown, at the beginning of the movements the shaft lies alongside the arms which are extended in opposite directions, the left arm being stretched towards the target and the right

away from it, and the arms are aimed as well as their extensions. At the moment the javelin leaves the hand, the arms are again fully extended in opposite directions, but reversed, as if the arms themselves were being thrown.

When any part is mechanized the human counterpart begins to lose the power of taking direct actions against the opponent. Thus when a club is being wielded the human fist and wielding arm cannot be used directly against the opponent, and can act only indirectly against him. No doubt an opponent could be hit by the fist which holds the handle, but the club would not then be used.

The wielder of a stone, shot, club, baghnak, knuckle-duster, boxing glove, caestus, sword, or spear, must go through the motions of hitting, clubbing, clawing, slashing, or thrusting at the opponent, because the fist, claws, knuckles, wielding arm, and other parts, are only slightly mechanized. The archer and the rifleman, however, when they deliver blows or thrusts, which they do by shooting at the opponent, do not need to make the fist and arm go forward, because the bow and arrow machine and the rifle machine are more highly mechanized. The archer however must still go through the motion, as he draws the strings, of separating the hands and drawing back the right hand as if preparing to deliver the blow. The action of separating the hands is also performed by the rifleman as he pushes forward his left hand to hold the front part of the stock and as he operates the bolt.

The archer and the rifleman have lost the power of performing many actions directly against the opponent. The wielder of the fists responds quickly to the movements of his opponent and anticipates them as skilfully as a lady anticipates the movements of her dancing partner, as is seen by the rapidity with which the positions of the fists and feet are changed. But the archer and rifleman must keep their hands and feet in fixed or nearly fixed positions, or they will not be able to aim; and cannot respond easily and quickly to the movements of the opponent.

The small degree of mechanization given by the fitting of

a caestus, club, sword, shot, javelin, or other type of weapon studied in the previous chapters can be realized by considering that nearly all the wielding machinery is human. The stocks, butts, power devices, sights, recoil mechanisms, pivots, triggers, and magazines, for example, of all these machines are wholly human and no attempts have been made to mechanize them.

Each type of offensive machine must possess all the parts and devices any other type of machine possesses. If a part or device is not provided as a mechanical part or device, it will automatically be formed and supplied by the wielder's body. Thus, for example, the club machine is provided with a partly mechanized arm and fist, but is not provided with a mechanical stock, butt, lock, front sight, rear sight, or recoil apparatus. These parts and devices are therefore automatically provided by the wielder's body. If any part or device is not provided, then of course the machine cannot work properly.

Each type of offensive machine is merely a variation of the fist or claw or other human machine. The club machine, for example, is a variation of the fist machine, the wielding arm and fist being given mechanical extensions. The human types of the machine therefore include all other types of the machine, and no type of offensive machine can be made that is not a variation of a human offensive machine. It will be shown later that machines like the bow and arrow machine, the crossbow machine, and the rifle machine, are merely variations of human offensive machines made by mechanizing a few of their parts. Probably the atom bomb machine is merely a variation of the human offensive machine, obtained by mechanizing and distorting the power apparatus rather more than it is mechanized and distorted by means of the gun machine. The production of the atom bomb machine probably marks a very small advance in the process of mechanizing the offensive machine.

No part of the human offensive machine can be completely mechanized. This is evident from Rule 2 which shows that a weapon cannot be formed only from mechanical parts and

without human counterparts. As a part is more mechanized, the human counterpart is more released from directly operating the mechanical part; and it then begins to appear as if the human counterpart plays no part in operating the weapon. Thus, for example, with some modern types of guided missiles, the immediate operator might be out of sight of the missile, and it might seem to anyone unacquainted with the ways weapons originate and develop that the weapon and wielder were very little connected. This would be a fallacy, and would demand the belief that the weapon was endowed with a degree of organic and sentient life sufficient to make it to some extent capable of acting by its own volition, a manifestly absurd belief. As has been pointed out above, the archer is released from the need for making his arm go forward to deliver the blow or thrust. The offensive machine is very little mechanized by means of a bow and arrow, and yet the archer's arm can seem to take no part in hitting the opponent. As mechanization increases the wielder's body seems to take less and less part in operating the weapon; but even a little study of weapons with reference to the human body shows that the dependence of weapons on human mechanisms never becomes in any way less through mechanization, and that the modern and complex weapons are as closely related to their human counterparts as the club is to the fist and arm.

Because each part of a weapon must have its human counterpart and be operated by it, it follows that every weapon is under human control. No weapon, of course, can take any action except in so far as it is moved and operated by its wielder or wielders, and the actions of a weapon can be only extensions of those of its wielder or wielders.

CHAPTER 21

THE CROQUET MALLET

APART of a mechanical weapon is always close to its human counterpart, unless it is in a transferred position. Hence it is usually easy to discover the part of the body from which a part of a weapon has been derived, by noticing the part of the body against which it lies. The croquet mallet is evidently related to the leg and foot, for it is placed, preparatory to hitting the ball, alongside the right leg and foot, with the shaft or handle alongside the leg and the head of the mallet alongside the foot; and in particular the handle is related to the leg and the head of the mallet to the foot.

The wielder could make a contrivance with his leg and foot for use as a mallet, but does not do so, and instead provides himself with a rudimentary mechanical copy of the leg and foot contrivance in the form of the mallet. This gives him several advantages. It releases his leg and foot from the task of directly propelling the ball (Rule 5); and saves his leg and foot from the jar and hurt that would be received through striking the ball. The artificial contrivance can also be distorted from the form of the human contrivance, and the head can be made harder and heavier than the foot. The face of the head can be made blunter and flatter and larger than the wielder's toe, and the ball can thus be more accurately directed.

The mallet is fairly closely related to the leg and foot in dimensions. It is usually about 39 inches long, and thus reaches about to the groin. The shaft is therefore about the length of the whole leg. It is not jointed at its middle as the leg is jointed at the knee, and the knee joint is not represented on the shaft, which corresponds to the contrivance that would be made by keeping the leg straight and stiff. The head of the mallet is rather shorter than the foot, and is

distorted to a shorter length. The shaft and head together somewhat resemble a leg and foot (Rule 1). The mallet is swung in much the same way as the whole leg and foot can be swung; and the actions of the mallet when being swung reproduce in a crude way the actions of a leg and foot when being swung. There can therefore be no doubt that the mallet is a rudimentary mechanical embryo of the contrivance that could be formed by the whole leg and foot swung to strike or hit an object. But the mallet is often swung between the legs. When it is so used, it probably serves as a rudimentary mechanical extension for both legs and feet. To understand the nature of the mallet therefore it must be studied as an implement that can represent either the right leg and foot or both legs and feet.

The mallet is held and wielded by both hands; and it must therefore be also a mechanical extension of the arms and fists. This is possible because biologically the arms and hands or fore limbs are constructed on the same plan as the legs and feet or hind limbs. The upper leg has one long bone, the lower leg two long bones; similarly the upper arm has one long bone, the lower arm two long bones; the arm is jointed to the body by a ball type of joint, the leg by a similar type of ball joint; and so on. Indeed biologically the arms are types of legs. Therefore because the fore limbs and hind limbs are similar structures, it seems a croquet mallet can form extensions simultaneously for the legs and feet and for the arms and hands or arms and fists; and if the head of a mallet is a copy of the foot or feet it can at the same time also represent the fist or fists.

The shaft and arms together form a kind of composite arm, partly human and partly artificial, to wield the rudimentary and distorted copy of the fists, mechanical extensions of the fists being formed by the head of the mallet, the mechanical extensions being transferred away from their human counterparts to the lower end of the mallet opposite the human fists. The right arm is placed alongside the upper half of the shaft, the right hand grasping the shaft at about its middle. The left hand grasps the shaft at or

near its top, with the forearm about at right angles to the shaft. The left elbow is placed against the body. The upper left arm does not move much, and the shaft when it is moved does not extend the actions of the left arm to any extent; and perhaps therefore the shaft is a mechanical extension for the right arm and left forearm only. The shaft swings round the hinge or pivot formed by the left elbow joint.

The mallet is thus a mechanical extension of two human contrivances, one being the contrivance formed by the arms and fists, and the other that formed by the leg and foot, or legs and feet if the mallet is swung between the legs.

Very often a mechanical contrivance serves simultaneously as an extension for two human contrivances. Thus, a walking stick serves as a mechanical extension for a leg and helps the leg by taking some of the weight of the body off the leg, and by giving a thrust on the ground to help the leg forward, and in other ways; and also at the same time serves as a mechanical extension for the arm, and allows a kind of long arm to be formed to push on the ground to help the body onwards and assist the leg. Several examples will be given later of parts of weapons which simultaneously reproduce two human offensive contrivances.

The shaft is approximately cylindrical, but swells as it approaches the head and diminishes quickly in girth as it enters the head. The upper half is not, as a rule, circular in section, but octagonal, with the octagon somewhat flattened at the sides of the shaft. The lower half of the shaft is usually circular in section at all parts.

Bindings are occasionally placed on the shaft, but usually the shaft is left bare; but the human barrel is rifled with eight grooves if the grip is of octagonal section, the ridges along the shaft making grooves in the skin and flesh of the human barrel.

The barrel is human, and formed by the hands. It is in two parts, one part being formed by the right hand fingers, at about the middle of the shaft, and the other part by the left hand fingers near the top of the shaft. The two parts

are therefore separated by about half the length of the shaft. The shaft has no movements relative to its barrel, that is it does not move through it as, say, a bullet moves through its barrel, and the barrel and shaft are fastened together. The axis of the human barrel coincides with the axis of the shaft. Since the mallet is swung approximately round the horizontal axis of the left forearm, all parts of the shaft move in arcs of circles round this axis; and therefore the shaft moves at right angles to the axis of its barrel instead of along the axis as a bullet moves. It will be remembered that somewhat similarly a caber moves at right angles to and not along the axis of its barrel. Apparently, a weapon or missile must move either along or at right angles to the axis of its barrel but cannot move in any other direction (Cp. Rule 10).

When the mallet is swung at the side, in most styles the right hand fingers are in front of and the left hand fingers are behind the shaft. The spirals formed by the spaces between the fingers are more nearly parallel to the axis of the shaft in the case of the right hand than in the case of the left hand, and the spirals of the left hand or upper part of the barrel may be in planes almost at right angles to the axis of the shaft. The pitches of the riflings of the two parts of the barrel are therefore not the same. The riflings of the lower part of the barrel, formed by the right hand fingers, have a steep left handed screw twist; those of the upper part of the barrel seem to have a slight left handed twist.

As has been stated, the interior of the human barrel is rifled by the eight ridges of the octagonal shaft. It is also rifled by its own devices, formed by the grooves between the fingers. The interior of the barrel therefore has a type of mechanical rifling and two types of human riflings on its inner surfaces. The human riflings are of two types because the pitches of the screw threads are different at the upper and lower parts of the barrel. The mechanical rifling is a crude counterpart of the human riflings, but correspondence is very remote, and the mechanical and human riflings do not fit into each other as, say, the riflings on the driving band of

a shell fit those on the interior of a gun barrel. A purpose of the octagonal ridges is to help the hands to obtain a good grip; and the ridges are therefore also chequering devices; and the mechanical rifling and chequering devices are combined and not separately mechanized.

If the mallet is swung between the legs the two parts of the barrel may be close together, that is the hands may be close together. The fingers of each hand may then be in front of the shaft; and the right hand or lower hand fingers then form left handed screw threads, and the left hand fingers form right handed screw threads.

The shaft is held against the palms of both hands, and therefore lies in the breech of the machine which is formed by the palms. The breech, like the barrel, is approximately cylindrical, and also like the barrel is rifled by the ridges of the octagonal shaft.

Riflings are represented on the lower part of the shaft when bands are painted round it. If the croquet set is for four players, one mallet may have one band, another two bands, another three bands, and the fourth four bands painted on it. The ostensible purpose of the bands is to distinguish the mallets and relate them to the balls and players, the third player for example usually playing with the mallet with three bands and the ball with three bands. But the bands are types of riflings, although of no direct help in spinning the ball. The bands are of slightly larger girth than the shaft, because of the thickness of the paint, and the slight ridges at the ends of the bands can be felt. Often the mallets and balls are distinguished simply by painting the balls different colours, one being painted say blue, another black, another red, and the fourth yellow, and a band of colour to match a ball may be painted on the lower part of the corresponding mallet.

The ball which is usually $3\frac{5}{8}$ inches in diameter is solid, spherical, and made of boxwood, beechwood, or other wood which does not easily split. Composition balls are also used. The ball is sometimes machined all over with fine lines which form a pattern of chequering. But sometimes the ball is not

machined all over, but has a band or bands of lines cut lightly in its surface, the first ball having one band, the second two bands, the third three bands, and the fourth four bands, so that a player with a mallet with say three bands painted on it will play with the ball with three bands of lines machined on it. On a set of balls on the author's table each band is 11 mm. wide, and is formed by 9 lines, the two outer or side lines of each band being cut rather wider and deeper than the inner ones. One ball, no. 2, however, has its two bands 12 mm. wide and formed by 12 lines, this ball being rifled slightly differently from the others, and perhaps has been made by a different workman or has been made at a different time from the others. The difference is apparent only with close observation.

The head is a solid cylinder with flat ends. Either face can be used to hit the ball; and when one face is used the mallet is reversed compared with its position when the other face is used (Rule 11). The head is socketed, with a hole through it to receive the tang of the shaft. The axis of the shaft is at right angles to the axis of the head; and a blow is therefore always given at right angles to the axis of the human barrel. The bottom of the mallet's head is occasionally cut away, so that it has a flat foot. It may be left bare, but sometimes a brass plate is screwed on, giving the head a metal sole.

The ball becomes part of the head of the mallet, and therefore an extension of the fists or feet, during the time the ball and head are in contact; and the connection between the ball and head is emphasized by the circumstance that the riflings on a ball, when the ball has bands machined on it, and on the mallet that hits it are of the same type and correspond in number, ball no. 4 for example having four bands of lines on it and being hit by a mallet with four bands painted on it.

The riflings or chequerings on a ball become partly transferred to the face of the mallet when contact is made; and the transferred markings can often be seen on the face. The impact of the mallet on the ball is violent, and although the

mallet is made of hard wood, the face is not hard enough not to take the impressions of the riflings and chequerings from the ball. New impressions are received each time the ball is hit, and some previously received may be nearly obliterated. On a mallet on the author's table impressions of the rifled bands of the balls, which were transferred to the faces of the mallet's head many months ago, can still be clearly seen, and will probably remain until the next game is played, when they will be nearly obliterated and new ones received. The ways in which parts and devices of weapons, or other mechanical instruments, can be transferred is well illustrated in the transferring of the riflings and chequerings of croquet balls to the faces of the mallets.

The riflings on the faces of the mallet are not sufficiently well transferred to be able to see from which ball they have been received, but because the mallet has four blue bands painted round its shaft, presumably it was used to hit the ball with four bands, and the riflings on its faces probably are types of riflings which correspond to those on the ball with four bands.

Mechanical sights have been fitted to croquet mallets, in the form of looking glasses fastened to them, in which the ball aimed at was reflected, or in the form of black lines painted on the mallets to help to guide the eye.[1] Although mechanical sights do not seem to have been of much use and have been discarded, a study of them would help to show how the croquet player aims; but the author has not seen mallets with these mechanical sighting devices and therefore cannot discuss them. Modern mallets have no mechanical sights; and since the devices are human little can be learnt about them, except in a general way.

The elevating devices of the croquet machine are not mechanized; and the ball is hit along the lawn in the direction of the axis of the mallet's head and at right angles to the axis of the barrel. The ball, however, can be made to jump, by hitting it against the ground, but the reaction of the ground is then made use of to give elevation to the ball. The

[1] *Cassell's Book of Sports and Pastimes.*

faces of the mallets are vertical, and not set at different angles to the vertical after the manner in which the faces of golf clubs are set. The trajectory of the ball is flat, and if the lawn is smooth is a straight line. The trajectory therefore differs from that of a ball thrown or hit through the air, whose trajectory is parabolic in form. There is, however, no fundamental difference in the types of trajectory, because mathematically a straight line is a limiting form of a parabola or other conic section, and also because a ball hit along the surface of a lawn, if the surface follows the shape of the surface of the earth, is hit along the circumference of a circle or ellipse.

A crack or bang is heard at the moment the croquet ball is propelled, and another one is heard when it has reached the end of its trajectory if it then hits another ball or the post, one report being heard when the missile is at the beginning and the other when it is at the end of its trajectory (Cp. Rule 9). A thud or smack can often be heard when the wielder of the fists hits his opponent, but a human weapon like the fist or claws is propelled silently, and a report is heard only when it reaches the end of its trajectory and the opponent is hit. The report when the croquet ball is propelled is distinctive, and different from the report when a golf ball or other missile is propelled.

The sound of the golf ball or bullet as it traverses its trajectory through the air can be heard by anyone near its trajectory as a kind of whistling or whining sound. The sound of the croquet ball as it traverses its trajectory and rolls along the lawn cannot easily be heard because a lawn does not act as a good reverberating material. But when a ball is hit or rolled along hard ground or along a board the sound can be very clearly heard, and somewhat resembles thunder. The sound of nine pins rolling has been compared by Washington Irving to distant thunder. The reader will remember that Rip van Winkle when climbing the mountain side heard "long, rolling peals, like distant thunder." When he entered the cavern and saw that a game of nine pins was being played, "nothing interrupted the stillness of the scene

but the noise of the balls, which, whenever they were rolled, echoed along the mountains like rumbling peals of thunder." Washington Irving, of course, exaggerated the noise made by the balls, but evidently believed the comparison of the noise of a ball rolling on a hard reverberating surface to that of distant thunder would carry conviction to the minds of his readers.

A distinctive noise is made by each type of the offensive machine as the blow or thrust is delivered. But each type of report is merely a variation of any other type; and the report heard when the gun machine or atomic bomb machine delivers its blow is similar to the report when, say, a croquet ball or billiard ball is hit; but increasing the degree of mechanization of the propulsive mechanisms makes the report of the gun machine louder than that of the croquet machine and that of the atomic bomb machine still louder. But no difference of principle is involved, because the gun machine or atomic bomb machine is merely a variant of the croquet machine or any other offensive machine, differing only in the degree of mechanization.

It was remarked above that the fist machine makes no noise as it delivers its power, and very little as the blow is given. This is because it is a highly efficient machine. In general, the more noise a machine makes in operation the less efficient it is. Therefore the gun machine is less efficient than the fist machine, and the atomic bomb machine still less efficient. There is indeed a loss of power at every stage of manufacture of the gun machine, and the loss in the making of the atomic bomb machine is very great. There is however almost no loss of power in forming the fist machine. This does not mean the atomic bomb machine is a less effective machine than, say, the fist machine or the bow and arrow machine. Offensive machines cannot be compared with each other for effectiveness, because a man killed by a blow from a fist or club or a thrust from an arrow is as dead as one killed by a bullet or an atomic explosion, and there are no degrees of deadness. But one type of offensive machine can be more effective for certain purposes than another type;

and a great number of people working together may find it more advantageous to compose an atomic bomb machine than to compose a multitude of fist machines.

No absolute advantages of course can be gained by increasing the degree of mechanization of a human machine, any more than, say, any absolute advantage can be gained by a man using a lever. It is commonly explained that when using a lever what is gained in power is lost in speed; and somewhat similarly what is gained in power by making for example an atomic bomb is lost in time. But the use of a lever may give advantages for raising a heavy weight and the use of an atomic bomb may give the advantage of allowing one big blow to be delivered instead of a multitude of small blows.

The name of the maker is often stamped on the head of the croquet mallet. The name device is not an offensive device, and does not add to the efficiency of the implement, but serves as an advertisement for the maker and a guarantee to the user. The device has no corresponding human counterpart, except perhaps in the tattoo marks sometimes made on the body to frighten an enemy. The name device has some correspondence to the name of a firm or organization stamped on a person's body. At some public entertainments to prevent people who have not paid gaining admission, the name of the organization or some other identification mark is stamped on the body, say on the inside of the wrist, of any person temporarily leaving the premises. This practice was common a few years ago in the author's parish. In elections in Ashanti villages, "pads of indelible ink are inserted in the lids of cigarette tins; and each elector having cast his vote, is required to press his thumb upon such a pad . . . to prevent him voting a second time. Europeans who desire to vote are, to the disgust of some of them, subjected to this check."[2] The maker's name is usually stamped on a croquet mallet, cricket bat, hockey stick, or other games club.

[2] *The Daily Telegraph*, February 3rd, 1951.

CHAPTER 22

THE GOLF CLUB

THE implement used by the golfer for hitting the ball is called a club. That it is a club is evident from its shape and the manner in which it is held and wielded. Also the word golf is said to be related to the German word kolbe, a club, and to the Dutch word kolf, a club, the name of the striking implement being given to the game itself. According to Strutt a game called club-ball played many centuries ago in England differed from the golf or goff played in his day mainly in being played with a curved instead of a straight bat.

The shaft of the wooden-shafted club is nearly conical in shape, tapering to its smallest girth near the head, but the shaft of an iron-headed club may increase slightly in girth from the place of smallest girth as the head is approached. The shaft is held by both hands, which form a barrel and breech for the club. The hands are placed close together, and a part of one hand is sometimes placed over the other. The parts of the barrel are closer together than when a thrusting spear is held, and the barrel is usually continuously formed. The shaft has no movement along the axis of the barrel; and both shaft and barrel move in a direction at right angles to the axis of the barrel which is also the axis of the shaft.

An artificial extension for the barrel is provided for wooden-shafted clubs by the strip of leather wound spirally round the grip. A kind of conical tube whose interior surface coincides with the exterior surface of the shaft is formed, and serves as an extension for the skin of the interior of the barrel and breech. The artificial tube has some correspondences of materials to the human skin when it is made of leather, for leather is made from skin and has many of its features and properties. A continuous and fairly regular

spiral groove is formed between the turns of the leather strip. The skin sinks into this groove at certain places as the hands make their grips, and impressions of the mechanical rifling are reproduced on, or transferred to, the interior of the human barrel; and the barrel becomes rifled with an elementary type of mechanical rifling as well as with its own riflings. The spiral groove formed by the leather thong has a left handed screw thread, and a pitch about the same as that of the rifled grooves of the right hand; and it seems the mechanical rifling is meant to correspond to the human riflings of the right hand. But the mechanical and human riflings do not fit. The left hand fingers are usually to the front of the shaft, and therefore form right handed screw threads which cross the mechanical rifling almost at right angles. The types of grips made by golfers vary considerably, and makers of golf clubs could not make spiral grooves to fit the spirals of the hands with any advantages, especially as the golfer seldom holds the shaft twice in exactly the same place or way.

The ends of the leather tube of the wooden-shafted club are usually secured by being bound with a few turns of fine twine, and the grooves formed between the turns make types of close riflings of different pitches from those formed by the leather strip. The hands become rifled with impressions from the twine binding at the top of the shaft, if they are in contact with it; and occasionally when the hands grip the shaft lower down, by the twine binding at the lower end of the grip.

The clasps which hold the shaft and hands together are not mechanized, and cannot therefore easily be studied. Some things can be known about them, in a general way. The clasps are formed by the fingers, each finger forming a clasp separate from but in conjunction with the clasps formed by the other fingers. The clasp formed by a finger is continued within the main part of the hand and through the wrist to the forearm. Each of the three joints of a finger forms a part of the clasp formed by that finger. The ability to form a clasp is given through the finger being made

capable of bending at three places. Some clasps are formed over or partly over others, when one hand is placed partly over the other. The clasps of one hand are reversed compared with those of the other, for the fingers of one hand go round the shaft in one direction and those of the other go round in the opposite direction. The clasps vary in tightness and in forms during the wielding movements; but are not undone, for the shaft does not leave the hands. They are formed differently by different players, and differently also by a player when wielding different types of clubs. The skin helps to form the clasps and varies in tightness during the wielding movements. Information about clasp devices can however be obtained more easily, and perhaps can only be obtained, by the indirect method of studying elementary mechanical models of clasps which can be seen on certain varieties of the offensive machine like slings and cross-bows.

The club is wielded by both hands; and its shaft therefore corresponds to and forms an extension for both arms, and its head forms a mechanical extension for both fists or hands. But the club is also probably a mechanical extension of the legs and feet. This is suggested by the fact that when the golfer is taking aim, or addressing the ball, the shaft is fairly close to the legs and feet with its head on or nearly on the ground. The human prototype of a wooden-headed club can be seen in the arm and fist, if the fist is placed palm downwards on the ground. The shaft then corresponds to the arm, and the head of the club corresponds to the fist, with the face of the head or hitting part corresponding to the forefinger side of the fist. But the human prototype of the club can also be seen in the contrivance formed by a leg and foot; and the action of the club in hitting the ball is somewhat similar to that of a foot when some object is hit or kicked with the side of the foot.

Clubs with iron heads, like the cleek, driving iron, mashie, niblick, and putter, have rudimentary resemblances to a leg and foot, but have less resemblances to a fist and arm than a wooden-headed club possesses. They probably reproduce

a contrivance that could be formed by an arm and hand to scoop up an object.

The elevating devices of the golfing machine are partly mechanized and the golfer does not directly give elevation to the ball. The hitting faces of the clubs are set at different angles to the vertical. Thus, the face of a wooden driver may be only slightly inclined to the vertical, and the ball is given little elevation when hit by this club; but the face of a mashie or niblick is more inclined, and the ball is given a greater elevation and is hit more up into the air. To change the elevation the golfer uses a club whose head's face is set at a different angle to the vertical, and the elevation can thus be more or less automatically changed by use of a different club. The rifleman elevates his bullet or ball by raising the barrel until the line along the sights points to the part of the target to be hit, and he has no mechanical devices to help him to move the barrel to send the missile at a different elevation. If the golfer always hit with the same power, it would be possible to know the range of each club. Indeed it is said the angles of the faces originally were set for the clubs to have definite ranges. Thus, the mid iron was originally designed for a range of 135 yards with the old hard ball.[1] But the power mechanisms of the golfing machine are not mechanized, and the amount of power that can be delivered by the golfer is infinitely variable. As a result of partly mechanizing the power of the gun machine, the ability to vary the power has been almost atrophied, and the rifle machine or howitzer machine for example delivers the same power whatever the range (Cp. Rule 6).

The elevation given by any club can be easily seen, if the club's face is held upwards and horizontal. The shaft is then set approximately at the elevation given to the ball, and its inclination to the horizon shows the angle of elevation, the shaft pointing in the direction of the shot.

The sighting devices of the golfing machine are not usually mechanized. But they are slightly mechanized when a line or band is marked on the top of the head of a wooden

[1] Marshall Whitlatch, *Golf*.

club to assist the eye in directing the club's head against the ball, *Figure 66*. On the offensive machine the sighting devices are primarily formed by corresponding knuckles of the hands, the fore-knuckle of the left thumb, for example sometimes forming the front sight and the fore-knuckle of the right thumb the back sight, a line being taken along the tops of the knuckles which form types of V sights. But it is difficult to discover which devices are used by the golfer and how he uses them to obtain his line of sight.

Markings or lines are cut lightly on the flat surface of the part of the head which hits the ball. These are rudimentary mechanical copies of the markings on the skin of the hands, transferred away from the hands to the head of the club at the opposite end of the shaft (Rule 8). Various patterns of markings or chequerings are used, each maker providing patterns that he thinks will allow the best grip of head on the ball. The patterns, for example, are sometimes in the form of rows and columns of marks like dots, sometimes in the form of parallel lines, sometimes in the form of a set of parallel lines cutting another set at an angle, *Figure 66*.

A common type of chequering is formed by a set of parallel lines crossing another set of parallel lines at an angle, so that many diamond shaped figures are formed. This type of chequering resembles that provided for the stock of a nineteenth century bullet-shooting crossbow at the small of the butt, or for the small of the stock and fore part of the stock of a double-barrelled shot gun. The purpose of the crossbow or shot gun chequerings is to help the hand to obtain a good grip of the weapon. The chequerings on a crossbow or shot gun are derived immediately from the hands, for the hands are in contact with them (Rules 1, 3, and 7); but those on the golf club only indirectly from the hands, for they are not in contact with the human hands but are in a transferred position on the face of the head of the club (Rule 8).

The golf club and the rifle are different types of weapons; but the golf machine and the rifle machine are similar machines differing mainly in ways of mechanization, and in each

machine some parts are mechanized that are not mechanized in the other machine. In some ways the golf machine is more highly mechanized than the rifle machine, in others less highly mechanized, as can easily be seen. For example, the stock of the rifle machine is partly mechanized by means of the wooden stock of the rifle, but that of the golf machine is formed only by the stock of the body. The elevating devices of the rifle machine are not mechanized, but those of the golf machine are partly mechanized by means of the differently inclined faces of the heads. The skin of the human barrel is given an extension in the golf machine by means of the leather tube which reproduces fairly closely the materials of the skin; the metal barrel of the rifle machine reproduces the materials of the skin of the human barrel much less closely. The rifle's stock has no chequerings cut on it, and the hands must provide the chequering devices which therefore are wholly human and unmechanized; the golf club has mechanical chequerings on the face of the club. The power machinery of the golf machine is wholly human, but that of the rifle machine is partly mechanized by means of the gunpowder or cordite or other explosive charge. The mechanisms which allow an infinite variation in the power charge are however not mechanized in either machine, and although the golf machine can easily use these mechanisms, in the gun machine, as has been pointed out, they cannot easily be used, unless the cumbrous and slow method is used of selecting cartridges with different amounts of explosives. And so on. It can therefore be understood that it is difficult and perhaps not possible to compare the degrees of mechanization of the two machines.

A wooden-headed club is sometimes loaded with lead. The club then has some close relationships to a life preserver whose head is somewhat similarly loaded. The head of the golf club is loaded for much the same reason as the head of a life preserver, viz., to add to the weight of the blow.

The ball becomes part of the club's head while the head and ball are in contact. There is a very close fit of ball and head during the time they are in contact, but no permanent

fastenings are formed, and the type of fastening that is formed allows separation without any drag of head on the ball. At the beginning of contact, a point contact is made. The ball collapses as the head continues its forward movement, and becomes flattened against the face of the club, and a surface is formed to match the face of the club. If, as is usual, the face is incised with chequerings, they will be reproduced on the flattened part of the ball, thus ensuring a good and accurate fit, with parts of the head and ball fitting into each other. The head and ball cease to be materially connected, probably when a second point contact is formed, that is when the ball has recovered or nearly recovered its shape and is again in contact with the head only at a point. The fact that the ball collapses and becomes flattened against the face of the club can be seen if the face is covered with chalk before the ball is hit. After the hit, the chalk will show the shape to which the part of the ball nearest the face has been deformed. The time and distance the head and ball are in contact varies; but it is said by some authorities that the ball and head should remain in contact for several inches of the arc described by the head. It is of importance that there should be a good "follow through", so that the head and ball may be fastened together for a considerable period; and it is said the greatest effort must be applied after contact has been made.

The ball has an irregular surface, the irregularities being caused by chequerings which are usually fairly deep. Various patterns of chequerings are provided. Presumably, ideally, the chequerings on the ball and on a club should fit into each other when contact is made; but it would be impossible to direct the club so that its chequerings fitted into those on the ball.

The inside of the ball is made by winding long narrow strips of rubber into a ball in somewhat the same way as wool is wound into a ball ready for knitting, but the strips of rubber are wound very tightly. Some years ago the rubber strips inside the golf ball were fairly wide, but those of today are often almost like shreds. The tightly wound interior is enclosed in a tightly fitting hard rubber case. In earlier days

the case was often of leather and stuffed with feathers. The golf ball is therefore either a stuffed ball or one with a core of coiled materials, and differs essentially from the solid type used in games like croquet, bowls, and billiards, and from the hollow type used in games like football and lawn tennis. The modern ball also differs from the type used in games like cricket, for the core of the cricket ball is stuffed with hair, wool, or other material. Therefore, although the stuffed ball, the solid ball, the hollow ball, and the ball whose interior consists of lengths of coiled materials, are all derived from the fist or foot, they are not developing in the same ways. It will become apparent as this work proceeds that parts of weapons besides reproducing parts of the offensive machinery reproduce also parts of the reproductive machinery. It will be shown, later, that the golf ball is developing to reproduce the testis, which is composed of lengths of coiled tubes. The solid ball also is developing to reproduce certain features of the testis. The hollow ball is developing to reproduce the bladder and indeed the inside of a football is called the bladder. The author has not yet discovered the part of the body represented by the stuffed ball.

Chapter 23

THE BILLIARD CUE

THE billiard cue nowadays is straight and cone-shaped. Its length is evidently related to the length of the arm of the player, for a player with a long reach usually uses a longer cue than one with a smaller reach. It is often made from a single piece of wood, but the part held by the right hand may be made of heavier wood, the balance of the cue thus being made more suitable for some players. When made in two pieces, the cue has a type of shaft and foreshaft.

In trying to discover relationships between dimensions of parts of implements and human parts it is obviously essential to study the implements as they are used by expert players. An ordinary player is often and probably is usually incapable of making human and mechanical parts work correctly together, and often selects and uses an implement which has little correspondence to its human counterparts. The same is true of all other types of mechanical contrivances; and it might be misleading, for example, to try and discover the human prototypes of a bow and arrow or club or spear by studying it with reference to the body of an inexpert wielder or of a wielder for whom it had not been made. Considerable difficulties have been encountered by the author in trying to discover, say, the human prototypes of parts of some clubs which are not used nowadays, because it is now difficult to know how some of them were held and wielded. It is however often possible to deduce how a weapon like a club should be wielded. Thus a club with a long and thick handle and a very heavy head obviously could only have been wielded correctly with both arms, a short and light one mainly with movements of the forearm, and so on.

The barrel for the billiard cue is in two parts, one being formed by the left hand fingers and the other by the right hand fingers. The right hand fingers as they hold the butt take its shape, and the skin and flesh of the fingers are

deformed through pressure so that they form parts of a cone; and the interior of the human barrel corresponds in shape to that of the surface of the butt. The axis of the part of the human barrel formed by the right hand fingers coincides with the axis of the cue, and is a continuation of the axis of the front part of the barrel formed by the left hand fingers.

The left hand fingers placed on the table form the front part of the barrel. The fore part of the cue rests in or on the "bridge" device formed by the thumb and forefinger. Because of its weight, it makes a slight indentation or groove in the skin and flesh in which to lie; and the cue is propelled along or over this slight indentation or groove, or fore part of the barrel. The fore part of the cue is therefore not placed in the hollow of the fist, that is in the main part of the barrel; but in a groove which is about at right angles to this hollow or barrel. This could be fairly well shown, if before placing the left hand on the table a pencil was placed in the hollow of the fist, and the left hand still holding the pencil, as well as could be arranged, was then placed on the table. The axis of the cue and pencil would be seen then to be about at right angles to each other. The barrel of the hand is thus provided with an extension or component at right angles to it, to receive the cue, by means of the flesh groove, which acts as the barrel for the foreshaft of the cue. The flesh groove compared with the main part of the barrel of the hand, or hollow of the hand, has therefore been turned through a right angle (Rule 10). The axis of the flesh groove, in which the cue rests, of course coincides with the axis of the foreshaft of the cue, and is therefore a continuation of the axis of the back part of the barrel, formed by the right hand fingers.

A study of the barrel formed by a billiard cue is of much interest and importance because it has many similarities to the barrel formed by an archer. The barrel made by an archer for his arrow will be studied later; and it will be seen that it is from the type of barrel formed by a billiard player or archer that the barrel of a rifle or other gun has been directly developed.

The billiard cue rests directly in the breech of the hand, if the palm is placed on the butt, the breech of any offensive machine always being formed directly or indirectly by the wielder's palm or palms. A part of the breech is formed by the palm of the left hand, but the cue does not rest in or against the palm, and therefore is not placed directly in the part of the breech formed by the left hand. The left palm, or part of it, however, is in contact with the surface of the table; and therefore it seems the surface of the table forms a mechanical extension of the breech, and indeed of the barrel also, since the left hand fingers are also on the table. This perhaps explains why the billiard ball has a flat trajectory, the ball always being propelled along the mechanical extension of the barrel and breech of the left hand, and indeed never leaving the barrel and breech, unless it drops into a pocket.

In certain circumstances the front part of the barrel is formed in other ways. For example, it may be formed by the forefinger being placed right round the cue, a kind of hook or ring being formed by the forefinger. The bouclée as this type of barrel is called surrounds the cue, which is darted through it. If the ball is under a cushion, the tips of the fingers may support the cue and form the front part of the barrel.

The right hand fingers move with the back part of the cue, but the left hand does not move, and the cue is darted over or along the flesh groove, or through the human forefinger ring groove, somewhat after the manner in which the darting spear is propelled; the darting spear however being moved through the main barrel or hollow of the left hand, but the cue being moved over or through a component of the barrel at right angles to the part of the barrel formed by the hollow of the hand. The billiard cue is thus a type of darting spear, and related to the darting spear of the ancient Egyptians or modern Ababdeh or Nubians.

The bridge is mechanized on occasions, when the ball is out of reach of the left hand and a rest is used. The rest consists of a long shaft which forms a long extension for the

left arm, and a cross whose plane is at right angles to the axis of the shaft of the rest. The fore part of the cue is placed in one of the four crooks or grooves of the head of the rest, according to the player's pleasure. The groove of the rest is a crude but recognizable mechanical reproduction of the human bridge formed by the left hand. The left hand holds the butt of the rest and is placed on the table; and the head or cross of the rest is therefore a mechanical type of the left hand rest which is formed at the butt transferred to the opposite end of the shaft of the rest (Rule 8). Sometimes the player uses a very long cue with the rest; and the cue then forms a very long and distorted extension of the right arm. The cue is usually placed over and alongside the shaft of the rest; and each arm is then provided with an artificial extension. It will be recalled that in Indian club exercises each arm is given a separate mechanical extension, and the mechanical extensions are not fused into one contrivance, as usually is the case when both arms are given extensions.

The head of the rest is not always in the shape of a cross, and various other types of rests can be found. A fairly common type has four grooves of different heights and depths in any of which the cue can be placed. The ordinary cross type of rest, also, offers a choice of two different heights and depths, because the fingers of the cross are not at right angles, and by turning the shaft a higher or lower rest can be used. There is less friction between the cue and the mechanical bridge than between the cue and the human bridge, and "a cue on a rest seems to run away from a player."[1]

The cue in former days had a large head, and was then a type of thrusting club. An illustration of Louis XIV of France and his friends playing billiards in 1694 shows them holding clubs with large heads resembling the mace type of cue used today in bagatelle.[2] Two types of cues are used in bagatelle, one resembling the modern billiard cue, and the other a mace whose head is pushed along the table, the mace

[1] *The Badminton Library*, Billiards.
[2] *Encyclopaedia Britannica*, Billiards.

type apparently being a survival of the type of billiard cue used in bygone days.

The head of the modern billiard cue is formed by the tip of the cue which has the shape of a frustum or slice of a sphere. It is made of leather and glued on to the blunt fore end of the cue. Although the head is small, it can deliver a powerful blow or thrust, because the momentum of the cue and right hand and arm becomes concentrated in it; and the heavy ball can be shot, if necessary, with considerable violence into a pocket or against a cushion or ball. The momentum of the cue and arm is concentrated in the head at the moment of impact, in much the same way as the momentum of the hand and arm and handle of a whip becomes concentrated at the end of the lash of the whip at the moment of the crack, the crack resulting from the momentum being suddenly transmitted to the air. Little noise is made as the momentum of the cue is transmitted to the ball, because the leather deadens the sound of the blow, and its elasticity helps to slow down the process of transference. The sound as one ball transmits part or all of its momentum to another ball can be heard as a sharp crack; a deep thud is heard when a ball hits a cushion.

The way the momentum of an object can be transferred to another object is well illustrated in the pastime in which the last of a row of coins in a line on a smooth table and in contact with each other is made to bounce off when the first in the row is hit with a coin. The momentum of the coin struck against the first coin in the row is transmitted to the point where it touches the first coin, transmitted to the part of the first coin where it touches the striking coin (Rule 7); transmitted across the first coin to its opposite point (Rule 8); transmitted to the point of the second coin in contact with the first coin (Rule 7); transmitted across the second coin (Rule 8); and so on; until the momentum is transmitted to the last coin in the row, which moves along the table with the momentum given originally to the striking coin. If a number of billiard balls are placed in a row, and a ball is hit against the first in the row, the last in the row may be hit

away, leaving the others almost unmoved, the last in the row moving off with the momentum given by the cue and hand and arm. The transference of the momentum occurs in accordance with Rules 7, 8, and 9. A crack or report is heard only when the striking coin or ball hits the first coin or ball in the row, and when the cue hits the striking ball. A crack or report is made by the offensive machine apparently only when the striking object is separated from the body it strikes; and no sound is made when momentum is transmitted between two objects in contact. This rule might seem to be violated in the gun machine, because the gunpowder or other explosive is in contact with the base of the ball or bullet; but most molecules or particles or atoms of the gases are at considerable distances from the base of the missile before they strike it, and hence the fact that there is a crack or report may be accounted for. Relatively to their sizes the atoms or particles are probably at great distances from the base of the ball or bullet before hitting it. At any rate, since the gun machine is merely another form of the billiard or croquet or golf machine, the crack or report must be produced according to the same principles.

The billiard cue is provided with a large extension for its head, while the cue and ball are in contact. The ball becomes fastened to the cue very lightly, and in such a way that contact can be easily and smoothly made and broken without any drag either of the cue on the ball or of the ball on the cue. Probably the fastenings begin as a point contact and end as a point contact. The ball is elastic, but probably is not much deformed by the cue; and adaptation of the cue and ball to each other's shapes is effected mainly by deformation of the diminutive head, or tip, of the cue. There are no chequerings on the ball, which is made as smooth as possible, and to prevent the cue slipping off the polished surface of the ball the leather cap or tip is chalked, thus also preventing the leather becoming polished and thus making a fastening difficult. The chalk also serves as a kind of link of materials between the leather cap and ivory ball.

The human rifling devices are not mechanized, for neither

the cue nor the ball is fluted or grooved or incised in any way. The rifling devices of the offensive machine are primarily formed by the fingers; and it seems the right hand fingers, at the butt, are directly used in spinning the ball. The ball of course spins as it rolls; but if "spin" is given to the ball, the ball is not hit in line with its centre, and probably the "spin" is then given by manipulation of the right hand fingers, that is by manipulation of the rifling devices of the right hand.

The surface of the table is made as level as possible. It is covered with baize, always green in colour, probably as a mechanical counterpart of the green grass of a lawn. Strutt says he thinks it probable that billiards "originated from an ancient game played with small balls upon the ground: and that it was, when first instituted, the same game transferred from the ground to the table," and he says also, "the improvement by adding the table answered two good purposes; it precluded the necessity for the player to kneel, or stoop exceedingly, when he struck the bowl, and accommodated the game to the limits of a chamber." The artificial extension of the lawn is transferred from ground level to the top of the table, i.e. from the lower ends of the legs of the table to the upper ends (Rule 8). As many characteristics of the close cut grass lawn as possible have been retained in the green baize covered top of the table. The baize reproduces the texture of the grass as well as can be arranged. It is made as nearly as possible of the same colour. An advantage of the use of baize is that the artificial or mechanical lawn does not need mowing, but a process somewhat similar to mowing occurs during manufacture of the baize when its surface is closely cropped or cut by a kind of mowing machine. The baize, like the grass, must be brushed and rolled, the rolling being seen when a hot flat iron is pushed over it. A disadvantage is that the baize cannot repair itself as the lawn can do.

The surface of the artificial lawn is rather higher than the surface of an ordinary table, and its height is determined probably fundamentally by the requirement that it shall reach to the crotch of the average player. The pocket into

which the ball is sent is related to the slinger's bag, archer's quiver, rifle's magazine, and pocket of the golfer's bag, as will be better understood later.

Chapter 24

THE RACKET

TENNIS, lawn tennis, and games of a similar type, have been developed it seems from a ball game called jeu de paume, or palm play, played in the parks and dry moats of French and Italian chateaux in the middle ages. The game developed in two ways, into a game played in enclosed or covered courts and into a game played in the open air. The open air game came to be known as longue paume, and the other as courte paume.

The striking implement in the game was originally the hand. Strutt, quoting a contemporary French author says, "The French palm play originally consisted in receiving the ball and driving it back again with the palm of the hand. In former times they played with the naked hand, then with a glove, which in some instances was lined; afterwards they bound cords and tendons round their hands to make the ball rebound more forcibly, and hence the racket derived its origin."

The hitting implement, or racket, was therefore originally formed only by the hand and arm, and composed only of human parts. The face of the racket was formed by the flat surface of the palm, and the handle by the forearm or by the whole arm. The dimensions of the head of the racket then corresponded to the dimensions of the palm. The length of the handle was equal to the length of the forearm when the palm was wielded mainly by movements of the forearm, but its length when the forearm and upper arm were kept more or less in line was equal to the length of the whole arm. The dimensions of the parts of the racket varied of course automatically with each player; and the racket therefore originally had the remarkable and useful property of varying in dimensions to correspond exactly to the dimensions of each player.

From the quotation from Strutt's book given above, it can be seen that the hitting implement was mechanized originally in two different ways, by covering the face of the racket, or palm, with a glove, and by covering it with a network of cords. One method was directed towards giving the face of the racket a continuous flat surface, the other towards giving it a surface consisting of a network of cords or strings. Two main types of rackets can be seen today. The first is represented by rackets whose faces have a continuous surface, like the table tennis bat and the battledore covered with parchment; the second by those with faces formed by a network of cords, like the lawn tennis, badminton and tennis rackets.

Certain advantages for hitting a ball are gained by mechanizing the hand. The bare and unmechanized hand and arm do not form a very effective or convenient implement for hitting a ball; for the hand may be made dirty or be hurt by being directly used as the face of the implement, it is too soft to form a good rebounding surface, and too irregular for a flat enough surface to be formed so that the ball can be directed with precision. It was probably seen that if the hand could be bound or covered in some way, many of these disadvantages could be overcome. But it is not easy to mechanize the hand to form a flattish implement; because any bindings or coverings, to be satisfactory in use, must be so shaped and arranged as to come into some correspondences with the skin, tendons, bones, and other components of the human parts of the striking implement. If there are not some correspondences, then the bindings or coverings will work loose, or fail to work well with their human counterparts. It is difficult and perhaps not possible by direct observation to discover how the hand arranges its parts and devices to form a hitting implement; but by a process of trial and error the early players of jeu de paume evidently discovered how to make and arrange mechanical counterparts of the human parts and devices satisfactorily enough to give certain advantages over the use of the unmechanized hand. The difficulty of discovering how to make mechanical

counterparts of the human striking implement is shown by the fact that makers of rackets are still trying to improve rackets, that is they are still trying to find better ways of mechanizing the human devices. The difficulty of discovering how the hand and arm form themselves into a hitting implement is also shown by the fact that makers of rackets seldom or never study the hand and arm directly, and instead rely upon a method of trial and error in making rackets; and players by using or refusing to use their products inform them whether or not the rackets work satisfactorily enough with their human counterparts; and indeed makers of games implements are, it seems, unaware that their products are rudimentary reproductions of parts of the bodies of the players.

By covering the hand with a glove, the hand was saved from being hurt or made dirty, and a somewhat flatter surface was formed. A larger hitting surface was also provided. The glove was a mechanical copy of the skin, closely following its form, and imitating its materials, and served as an extension for it, overlying it. When it was padded, the flesh underlying the skin was also copied and given a rudimentary mechanical extension; and the artificial flesh lay underneath the skin of the glove as the flesh lies under the skin of the hand, the skin of the glove being transferred off the surface of the hand to the exterior surface of the padding (Rule 8). The artificial skin and flesh and the human skin and flesh worked together and came into fairly good working relationships. Thus, for example, when the ball was hit by the centre of the palm of the glove, this part of the glove directly took the impact of the ball, the padding or artificial flesh underneath it softened the blow for the human skin which also felt the impact but in a lesser degree; and the human flesh of the centre of the palm was almost relieved of the need for softening the blow for the rest of the hand. The human and the artificial parts thus worked together; and it is not difficult to see that all other corresponding human and artificial parts somewhat similarly worked in harmony.

Broadly speaking there are three main types of gloves.

The first type is made of skin. The ordinary kid glove, as worn every day, is of this type. The second type is also made of skin, but padded, the padding being of wool, fur, hair, or other soft material: and the padding may be under the skin of the glove or be in a transferred position on the outside. The kid glove lined with wool or fur or covered with fur is of this type. The third type is the knitted or crocheted glove. The knitted wool glove is of this type. The lady's open work crocheted glove is also of this type.

A lawn tennis racket has a frame. This suggests and reveals that the gloved hand has a frame. A glove is made without a frame, and until fitted to the hand is consequently limp and shapeless. A frame is provided by the hand, partly by its surface and partly by its edge; and when say a kid glove is fitted to the hand, the frame of the hand gives it a shape and makes the skin of the glove become taut. The shape of the edge of the frame of the hand can be seen if the bare hand and fingers are placed flat on a sheet of paper, and a line is traced round the hand and fingers with a pencil. This gives the outline of the frame formed by the edge of the hand which mainly keeps the shape of the glove. When the glove has no fingers, the outline of the frame provided by the hand can be obtained by tracing a line round the hand and fingers, without entering the spaces between the fingers. This frame has the shape of an oval, approximately, and is not unlike the oval frame of a modern tennis racket.

A direct study of the hand reveals it has an internal frame, formed by the bones; but does not easily reveal it also possesses an external frame, and indeed it cannot do so, for the body can form a multitude of external frames, and the type of frame it forms depends on the type of garment or implement fitted to the body. That the hand possesses an external frame becomes evident only when this frame device or contrivance is mechanized and made to exist partly outside the hand, say as the frame of a tennis racket. It can then be seen that the hand has a frame to support and give shape to a glove. It can then also be realized that all parts of the body form external frames which support and give

shapes to clothes. Thus, for example, the leg forms a frame which gives shape to a stocking when worn. This frame is of a different shape from that of the hand. It is tubular, and any section at right angles to the leg is approximately a circle. The trunk and arms form a frame which stiffens and gives shape to a coat or jacket. Because each part of the body can provide a frame, the maker of a stocking, glove, coat, or other article of apparel, does not need to make a frame for the garment. Occasionally the frame of some part of the body is partly mechanized and partly externalized as for example when the shoulders of a coat are padded or stiffened to help the coat to keep a required shape. The internal frame, or skeleton, is also sometimes mechanized, as for example in the corset, which is provided with a framework of bones, or artificial ribs, at right angles to the human ribs which are their human prototypes and counterparts (Rules 1 and 10). The boot or shoe is provided with a rudimentary copy of the external frame of the foot, and can keep its shape nearly without help from the human frame. Indeed badly fitting boots or shoes impress the shapes of their frames on the foot, and distort the foot to the hurt of the wearer. If a limb is broken its external and internal frames collapse, and a surgeon then provides a temporary external frame of splints and bandages and plaster to help the injured limb to rebuild its inner frame which when repaired will then keep the shape of the outer frame.

The frames of parts of the body are partly reproduced mechanically by such contrivances as coat hangers, boot lasts, boot trees, and the dummies of parts of the body on which garments are hung in shop windows. Broadly speaking external frames are of two main types, one being an edge frame type and the other a surface frame type; but the types are seldom sharply distinguished and often one type has features of the other type. A coat hanger, if cut from a thin plate of wood or metal, is an edge type of frame, and reproduces merely the top edge of the shoulders and sometimes also the sides of the neck. A tailor's dummy on which a man's coat or woman's dress is hung has a surface frame,

and reproduces the surface of the body, or parts of it, and thus gives the shape of the body to the garment. Steel body armour has a surface frame, and can keep its shape, but not its position, without much help from the frame of the body. When wearing steel armour the body is provided with an artificial exo-skeleton; and then reproduces certain features of creatures which have an exo-skeleton, or skeleton on the surface of the body. The armadillo, for example, has an exo-skeleton, made up of boney plates. Chain armour requires the surface frame of the body to keep its shape; and similarly armour made of leather or other soft material more or less depends on the surface framework of the body to keep its shape. By starching a garment the surface frame of the body can be better reproduced, the garment then being more able to keep its shape, and the wearer of a starched garment is provided with a crude type of exo-skeleton. A skirt has a frame provided by the waist and abdomen, and the parts of the skirt round the legs hang from this frame and have a somewhat cylindrical shape. The woman's skirt is provided with a stiffer framework round the legs when it has hoops, as in the crinoline. The infamous "boot" of olden days reproduced mechanically the external frame of the leg or legs, and was used as an instrument of torture. It was purposely distorted in size, and "The legs were forced into a strong case and wedges driven in until bone, muscle, and marrow were crushed together."[1]

When a mitten, or glove without fingers, is made of skin, the composite contrivance formed by the hand and mitten has a continuous and fairly flattish surface. If the mitten is made of soft leather the frame is supplied mainly by the human frame contrivance formed by the edge of the hand and fingers, but partly also by the frame formed by the surface of the hand and fingers. Sometimes the edge frame of the hand is partly mechanized by a seam sewn round the edge of the mitten, which makes the mitten fairly stiff and rigid. For example, a baseball player's mitt is usually laced all around its edge with a leather thong, so that the edge

[1] *Chamber's Dictionary.*

becomes stiff, and the frame thus formed by the stiff edge almost keeps the mitt in shape without the help of the human edge frame. The complete frame of course is formed by the human edge contrivance and the mechanical edge contrivance. A gardener's mitten or glove also often has a rudimentary edge frame, formed by a stiff seam round its edge. But the edge frame is never stiff enough to keep the shape of the glove without help from its human counterpart formed by the edge of the hand and fingers.

Another type of frame is formed when the skin of the glove is very hard and stiff. The frame is not then formed by its edge, but by its surface. This type of frame is formed, for example, when a flat piece of hard and stiff leather is sewn on to the front or palm side of the glove, as in the game of jeu de paume au tamis which will be described later.

When a knitted woollen mitten is worn, a fairly flattish surface is formed when the hand is made flat, the flattish surface of the mitten of course being given by the surface frame of the hand. The edge of a woollen mitten is never very stiff, and a mechanical edge type of frame is therefore never well developed; and the edge frame is formed mainly by the edge of the hand and fingers. The surface of the composite contrivance, formed by the hand and mitten, is formed by the network of knitting. If the knitting is close, the surface may seem almost continuously formed; but when it is very loose, as in the lady's open work mitten, a very distinct network pattern is seen.

The human prototype of the frame of the lawn tennis racket can now be seen to be the frame contrivance formed by the edge of the hand as for example when wearing a glove or mitten. The human prototype of the handle of the racket is obviously the arm of the wielder, for the handle is a type of mechanical arm and provides an artificial extension for the arm. The network of strings of the racket corresponds to the network of an open work knitted or crocheted glove or mitten.

The complete arm of the lawn tennis machine consists of the arm of the player and the handle of the racket, the handle

forming a mechanical extension for the arm. The complete frame consists of the frame of the player's hand and the frame of the racket. The mechanical part of the frame is not near the hand, but is in a transferred position, at the end of the handle opposite the hand (Rule 8), and has a position corresponding to that of the head of a club.

During the wielding of the racket, the forearm and the handle are rigidly joined, and form a single contrivance, and neither can have movements independent of or relative to the other. The frame of the hand and frame of the racket also always have similar movements. The fact that the movements of the arm and handle are similar is sufficient by itself to show that the arm and handle are related and that the handle is derived from the arm. Similarly, the fact that the movements of the frame of the hand and of the frame of the racket are similar is sufficient by itself to show these human and mechanical contrivances are related and that the frame of the racket is derived from the frame of the hand.

The human prototype of the network of cords or strings of the racket's head could be known if the human prototype of the network of an open work glove or mitten could be discovered. But it is not easy to discover the human prototype of the network of a glove. The human prototype of an ordinary skin glove is obviously the skin of the hand, as can at once be seen from the fact that the skin of the glove overlays the skin of the hand, and is composed of somewhat similar materials, and from the fact that each part or device has similar actions and movements to those of the part or device of the skin of the hand next to which it lies. The network of a glove also lies over the skin of the hand, and must therefore be related to it; but exactly how it is so related is not clear to the author. Perhaps one of his readers will be able to solve this problem.

The lawn tennis racket's handle is rather longer than the forearm but is not as long as the whole arm; and it seems its length is decided by the fact that it is meant to serve sometimes as an extension for the forearm and at other times as an extension for the whole arm. It serves as an extension

for the forearm when it is wielded mainly with movements of the forearm, that is when the elbow is bent and the forearm has much movement relatively to the upper arm. It serves as an extension for the whole arm when the forearm and upper arm are kept in a more or less straight line as the stroke is made, the racket being wielded by the forearm and upper arm together as a single contrivance. To make the handle come into closer correspondence to the length of the arm for certain strokes, the handle is gripped higher up, thus shortening the extension of the arm.

The handle is connected to the body by clasps formed by the hand at the grip, each finger forming a clasp separate from but in conjunction with the clasps formed by the other fingers. A clasp is also formed by the thumb, on the opposite side to the clasps formed by the fingers. The clasps are not formed merely by the fingers themselves, but extend through the hand and wrist and forearm; but it is difficult to study them directly. The clasps which connect the frame to the handle of the racket are formed at the throat of the racket; and these clasps must be copies of the human clasps which hold the frame of the hand to the arm, that is they must correspond to the clasps which hold the hand and arm together at the wrist. But clearly the mechanical wrist fastenings formed at the throat of the racket are extremely crude copies of the wrist fastenings, and have none of the flexible properties of the wrist fastenings.

When the handle of a lawn tennis racket is made of wood, it consists merely of a single shaft; but when made of metal sometimes bifurcates and becomes two rods at the throat. The two rods then reproduce features of the two bones of the forearm, the radius and the ulna. Steel shafts are sometimes fitted to badminton rackets; and sometimes the shaft is a single rod, but sometimes is a type of double rod joined at intervals along its length. The latter type of handle also reproduces features of the two bones of the forearm of the wielder, but more closely reproduces features of the two bones of the forelimbs of creatures which are not fully separated but joined for a part of their lengths, of creatures

for example like the rabbit whose radius and ulna are fused or joined together for part of their lengths, or the frog in which the radius and ulna are completely fused, the only indication of their dual character being a groove along the length of the bone. Tennis and badminton handles seem therefore to be reproducing certain of the features of the bones of such creatures, in a very crude manner.

The barrel and breech are formed directly by the right hand only, unless the racket is held with both hands. As has been explained, the human part of the barrel of the offensive machine is always formed by the fingers, and the breech by the main part of the hand; and the interior surface of the barrel is formed by the insides of the fingers, and the interior surface of the breech by the surface of the palm. Nowadays the grip of the handle of the racket is usually covered with a rubber tube or a leather thong wound spirally. These devices provide extensions for the skin of the interior of the barrel and breech and reproduce its materials more or less closely; and the handle is then enclosed in the composite barrel formed by the hand and fingers and tube. The spiral groove between the turns of the leather thong is a type of rifling. It usually has about seven or eight turns, and has a left handed screw thread, probably intended to match the left handed screw threads of the right hand finger grooves. The pitch of the spiral, or mechanical rifling, is therefore about the same as that of the human riflings. The mechanical and human riflings do not fit into each other; and the mechanical rifling is only a rudimentary copy of the human riflings.

In recent years it has become the practice to paint the shoulders and throat and part of the handle with cellulose paint; and the cellulose paint forms a type of artificial skin, which lies over and covers the mechanical parts in somewhat the same way as the human skin lies over and covers corresponding human parts; and it is evident the artificial skin copies the natural skin and is an elementary extension of it transferred to the surfaces of the mechanical parts. At present there are only very remote and scarcely recognizable

correspondences between the materials of the artificial and natural skins.

There is little to distinguish the front from the back of the modern racket. But the strings at the top and bottom are so arranged that they are "smooth" on one side of the face and "rough" on the other, the different sides of the racket being thus distinguished. The front and back of the early racket formed by the bare hand or by the hand bound with cords and tendons were used to hit the ball, for "a French writer speaks of a damsel named Margot, who resided at Paris in 1424, and played at hand-tennis with the palm, and also with the back of her hand, better than any man"; and the writer adds that "at that time the game was played with the naked hand, or at best with a double glove."[2]

There is never any discontinuity in the process of mechanizing the offensive machine; and the modern lawn tennis machine has been developed only gradually from the jeu de paume machine whose hitting implement was formed simply by the bare hand. Various intermediate types of the machine between the human machine and the lawn tennis machine can be seen, many of them being in use today. In some types the mechanical part of the head of the racket is on the hand, and the arm has no artificial extension; in some types the mechanical head is nearly off the hand; in other types it is fully transferred from the hand to the end of a handle or artificial extension of the arm. A few types of rackets used in varieties of the game of tennis will now be studied:—

The jeu de paume au tamis bat

The mechanical part of the racket used in this game is not separated from the hand, and is formed by a piece of hard, dried leather stitched to the palm of a glove, the core of the racket being formed by the hand within the glove. The game as it was played about 1865 has been thus described by Dr. A. L. Fisher:—

"A game played with a glove, to the front of which is fixed a stout piece of untanned hide, nine inches long by five

[2] J. Strutt, *Sports and Pastimes*.

wide, which is so stitched as to form, when dry, a curve corresponding to that of the hand, and hard as wood. The ball is an inch in diameter, formed of strong white leather filled with powdered egg-shell or sand, so as to have no rebound, and requires to be always struck over hand. On beginning the game, the player throws the ball on to a horizontal *tamis* or sieve of a drum shape, formed by a horsehair tissue drawn over a wooden frame.

"The players are divided into two opposite sides, as in our ordinary game of Tennis; each party tries to send the ball to the opponents in such a way that they cannot return it, and succeeding in this, they gain one point. There is near the town of Amiens a place called La Hautoi, where the game may be seen any Sunday afternoon during summer. As a proof of the difficulty of the game, I may state that the ball is seldom returned more than three or four times."[3]

The game is played in a vast arena, about 120 yards in length, by 12 players, six on each side. The tamis is used only in the delivery of the "service"; it resembles a segment of a drum, and the horse-hair of which it is made, is sufficiently elastic to enable the server to throw the ball on to its surface, and strike it on its rebound.[4]

The table tennis bat

The face of the table tennis bat somewhat resembles that formed by the stout piece of untanned hide used in the game of jeu de paume au tamis described above, and is a modified form of it nearly pushed off the hand and provided with a short handle. The sizes of the bats used in the two games are also about the same, but the face of each is considerably larger than that formed by the bare palm, but about equal to the size of the face that could be formed by the hand with fingers outstretched. The face of the table tennis bat is not quite off the hand, for the forefinger and parts of the hand near it are placed against the back of the bat. The frame is

[3] *The Game of Pallone.*
[4] *The Badminton Library,* Tennis.

formed by the entire surface of the bat which therefore has a type of surface frame as distinct from the edge type of frame of the tennis racket.

The face of the bat is usually covered with a type of artificial skin, whose mechanical prototype is the skin of a glove whose human prototype is the skin of the hand. Correspondence of materials to the skin of the hand is remote when the artificial skin is made of sandpaper, but is closer when it is made of rubber or cork. The artificial skin is chequered, the fine bits of glass of the sandpaper forming the chequering on the sandpaper covered bat, and the raised dots or other devices on the rubber skin forming the chequering when the bat is rubber faced. The chequerings correspond to and are mechanical extensions of the chequerings of the hand, formed by the multitude of small depressions and projections on the surface of the human skin. The purpose of the mechanical chequerings is to help to obtain a better grip of the ball.

The skin of the hand, it can now be seen, is reproduced artificially on a considerable variety of implements. It is reproduced, for example, by the leather thong on a golf club handle, by the rubber tube or leather thong on a lawn tennis racket, by the glove and stiff leather face of the jeu de paume au tamis bat, and by the sandpaper or cork or rubber facing of the table tennis bat. It is also reproduced by the glove of a caestus or boxing glove, by the skin or kid glove worn every day. Sometimes correspondence of materials is fairly close, as is always the case when the artificial skin is made of the skin of an animal. It is fairly close also when the artificial skin is made of cork, for cork is the skin of a tree. It is very remote when the artificial skin is made of sandpaper, although certain types of paper like parchment are made of skin. Attempts are now being made to reproduce the skin of the throat and shoulders, by means of the cellulose paint on lawn tennis and badminton rackets, and the skin of the leg or arm by the cellulose paint or varnish on the hockey stick and golf club. The artificial skin is reproduced differently on different types of weapons; and

probably each type of skin reproduces certain features of the human skin that are not reproduced by other types. It will be seen, later, that many other types of mechanical implements also reproduce the skin of the body, always of course extremely crudely.

The tamburello

A glance at the hitting implement used in this game, the tamburello (*Figure 26*), shows that the mechanical part of the implement is not quite off the hand, and that the hand and fingers help to form the back part of the head. The hitting surface evidently corresponds to the taut skin of a glove or mitten, and therefore corresponds also to the skin of the hand. The handle is human, and formed only by the wielder's arm. The clasps which hold the handle, or arm, to the frame are formed partly by the fingers, but partly also by the strap and part of the frame within the hand which form complementary devices to those formed by the palm and fingers to hold the hand and mechanical part of the implement together. The throat of the tamburello is formed by the wrist and part of the hand near the wrist, and is human. The shoulders are formed by the parts of the frame within the hand and near the thumb and little finger. The vellum of the face is not stiff enough to form its own frame, and the frame is mainly an edge frame, formed by the framework round the circumference of the tamburello. The part of the grip within the hand forms a kind of handle. In the table tennis machine, this handle is modified in form and turned through a right angle (Rule 10), and becomes its short handle. The game of tamburello has been thus described by Dr. A. L. Fisher;—

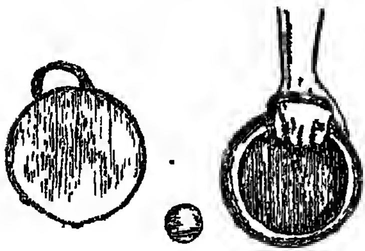


FIG. 26.
TAMBURELLO RACKET, WITH HUMAN HANDLE
A. L. Fisher, M.D.

"Tamburello is a companion game to Pallone. It is played

with a ball about the dimensions of an ordinary-sized orange, made of worsted or strips of cloth, covered with wash-leather. It is struck by an instrument made like a tambourine, about nine inches in diameter, with a remarkably strong frame, by which it is grasped, and covered with very stout vellum.

"Tamburello is occasionally introduced as a change by the members of the Pallone company. It is played in the same locality, is subject to all the same rules as the latter, and, as an exhibition it is almost equally interesting to witness: It has also the advantage of giving the choice of a much less fatiguing game than that of the Pallone."

A study of *Figure 26* helps to show that although, according to Rule 8 a device can be transferred only to the opposite end of a part, yet the transference can happen only gradually. The head of a modern lawn tennis racket it might seem has been suddenly transferred away from its human counterpart to the opposite end of the handle. But in the tamburello machine, as we are now seeing, the mechanical head is still held by the hand and arm; in the table tennis machine the hand and arm are around the handle, but still close to and in contact with the head of the bat. But occasionally the hand may not be actually in contact with the face of the table tennis bat; and at these moments it is at the end of the handle opposite the face of the bat, an almost imperceptible process of transference having occurred. Thus, it is beginning to become clear, the transference to the end of a part is never sudden and probably can be only gradually accomplished. No doubt an exhaustive study of all types of clubs would show somewhat similarly that although the head of the typical club is far away from its human counterpart, which is the fist at the grip, yet the process of transference has been effected only gradually.

The battledore

The face of the battledore is often made of parchment; and the parchment, which is made of skin, serves as a mechanical extension of the skin of the hand. The frame is an

edge type of frame; and is a mechanical copy of the frame of the hand, distorted in shape and transferred away from the hand to the opposite end of the handle which itself forms an extension for the wielder's arm. The clasps which join the frame and handle are formed by the devices at the part of the battledore where handle and frame meet, the mechanical clasps being rudimentary copies of the human clasps which are formed at the grip to hold the handle to the arm.

The chistera

The front and back of the hitting implement used in the game of pelota are easily distinguished. The word "pelota" means literally " ball ", but the word is also used to describe the game, which is played in Spain, Portugal, the South of France, and parts of South America. There are many varieties of the game; and the hitting implement varies from the bare hand to the grand chistera, or schistera, which is a long, narrow, wicker-work basket, strapped to the wrist and forearm and extending much beyond the hand. It is " rather more than two feet in length, and shaped like a curved canoe or basket; "[5] and the ball is caught and thrown with its help, rather than struck. The human prototype of the chistera seems to be the hollowed hand having the thumb placed along the side and the fingers brought to a point. The basket is made, however, much longer than its human prototype; and the cords or strings of the ordinary racket are represented by the wicker-work of the basket. The palm and fingers of the pelota machine are formed partly by the basket and partly by the palm and fingers of the wielder placed partly along and behind it. The hand and fingers are mechanized by means of the basket, and the mechanical part of the implement is not off the hand completely. The game is played against a wall, and is said to have originated from hand-ball. The scoring is as in tennis; but the balls are larger and heavier than tennis balls (not lawn tennis balls), which they resemble in appearance. In Mexico the game is called Jai Alai; in the Basque provinces Jugar al Blé.[5]

[5] *The Badminton Library,* Tennis.

The crosse

In the game of lacrosse, the network and frame of the crosse correspond somewhat to the chistera of the game of pelota, but the part which hits the ball or catches or throws it, is fully transferred to the end of a handle, which forms an extension for the arms.

The fives glove

The fives glove is a padded glove, not transferred away from the hand, nor provided with an artificial extension for the arm, that is, it has no handle. It will have been noticed that the lawn tennis racket, the badminton racket, the table tennis bat, and other types of rackets, do not reproduce the padding of a glove. The padding, so far as the author knows, has never been transferred away from the hand to the end of a handle; and it seems the padding or artificial flesh is represented in hitting implements only in games like fives and boxing; but is commonly represented in defensive contrivances.

The cricket batsman's glove

Ways in which the hand can be mechanized by means of gloves, cords, tendons, tapes, and other devices, for forming an implement for stopping, catching, or throwing a ball, can be understood by studying cricket batsmen's shields and gloves, baseball players' mitts, and similar contrivances.

At one time the cricket batsman covered the backs of his hands with flat oval rubber pads. When the hands were opened, each pad formed a flattish oval surface, stiffened and held in position by the hand behind it, and somewhat resembled the face of a modern table tennis bat, but placed over instead of nearly beyond the hand. Nowadays the cricket batsman's gloves usually have separate fingers. The fingers are padded at the back only, and the padding is a rudimentary copy of the flesh of the fingers, the skin of the glove reproducing in a rudimentary way the skin of the fingers.

Cricket batsmen's gloves are not used for hitting the ball, but for protecting the hands from the ball; and are therefore

defensive and not offensive contrivances; and a study of them properly belongs to a study of armour.

Baseball gloves

The baseball catcher's mitt looked at from the back appears to be a type of fingered glove; but the fingers are unable to move relatively to each other because the front surface is continuously formed, and has a flattish and heart-shaped surface. There is a partial division between the thumb and the rest of the glove, and the thumb is held loosely to the rest of the glove by cords. Cords lace the mitt all round the edge; and the shape of the mitt is kept partly by the edge frame, and partly by the surface frame formed by the fairly stiff material of the mitt. But the frames are not rigid enough to preserve its shape without the complementary frames formed by the hand and fingers within the mitt. The handle of the contrivance is human, and formed by the wrist and forearm

The fielder's glove is more like an ordinary fingered glove, but is padded at the palm and insides of the fingers with a type of artificial flesh. The thumb and forefinger are loosely connected by thongs, but the four fingers are not connected by thongs.

The baseman's mitt is somewhat similar to the catcher's mitt, but has no separate fingers; and a flattish surface is formed at the back as well as at the front. The thumb is loosely connected by thongs to the main part of the glove; and a rudimentary frame is formed by the edge of the mitt which is laced all round with a thong. The handle of the contrivance is formed by the forearm, and is not mechanized.

Chapter 25

CRICKET AND FOOTBALL IMPLEMENTS

THE cricket bat is placed fairly close to the batsman's legs, with its butt-end on the ground. It is therefore evidently related to the contrivance formed by his legs. But since it is held by both hands and wielded with pronounced movements of the arms, it also evidently forms an extension for the arms. It is used as a shield as well as a weapon, to defend the wicket and the batsman's body, and possibly it is a mechanical extension of other parts of the body, but the author is not sure of this.

It has been explained by the author in a previous work that the wicket represents the batsman's legs and pads. The bowler is not supposed to bowl directly at the batsman's legs, and instead must bowl at the wicket which is a contrivance provided to represent his legs and pads. From the bowler's end of the pitch, the wicket's width appears to be about the same as the width of the batsman's legs and pads, and the top of the wicket appears to be about the same height as the top of the pads. The wicket however cannot vary in dimensions to correspond to the dimensions of each batsman; and it seems represents the legs and pads of the average batsman. In some games, as for example in baseball, the target presented to the bowler or pitcher has the property of being able to vary in dimensions to correspond to the dimensions of each batsman's body. The cricket wicket is less flexible in this respect, and a wicket of a standard size must represent each batsman in turn. In the children's game of French cricket, in which the legs are defended by anything handy held in front of them like a stick, cricket bat, or lawn tennis racket, the target is formed by the batsman's legs, and therefore its dimensions necessarily and automatically vary with each batsman, and correspond exactly to the dimensions of the legs of each batsman.

The pad, or leg guard, forms a kind of armour for the foot, leg, and lower part of the thigh, and reproduces in a rudimentary mechanical form the bones, flesh, and skin of these parts. There are two main types of pads.

In the first type, there are a number of parallel vertical canes, usually from six to eight in number, of about the length of the lower leg, arranged round the front and sides of the leg, and held together by a covering of padding and skin, the skin covering the pad completely. The knee is covered with two or three horizontal "rolls". These are pads held to each other by the skin of the pad so that the upper part of the pad can move with the upper leg. There are no canes in the parts of the leg guard above the knee.

The canes are approximately parallel to and lie alongside the two bones of the lower leg, the tibia and the fibula; and are mechanical reproductions of these bones. The canes of the leg guard are more numerous than the bones of the leg, because the mechanical devices are distorted in number Usually a part of a weapon reproduces the bones of the leg or arm as a single shaft. Thus the golf shaft does not reproduce the three bones, the humerus, radius, and ulna, of the arm separately, but reproduces them all by a single shaft But in the cricket leg guard, the two bones of the lower leg are represented by six to eight canes.

The flesh is reproduced artificially by the padding under the canes. The skin of the leg guard, which is often made of buckskin, reproduces the skin of the wearer's leg.

The lower leg bones of the cricket batting machine are therefore formed by the two bones of the lower leg and the canes of the leg guard. The flesh is formed by the human flesh and padding; and the skin by the skin of the leg and skin of the leg guard. When the ball hits the leg guard, the human and mechanical parts work together to stop or deflect it The leg guard of course by itself can do nothing; and it must be held in position and be moved by the leg. Since it is strapped to the leg, human and mechanical parts necessarily move together and have similar actions.

The second type differs from the first type of leg guard in

that the skin does not cover the pad completely, and there are vertical slits between the canes, the slits being useful for purposes of ventilation. This type is called the skeleton pad, evidently because the skeleton of the leg guard can be seen.

There is another type, intermediate between these two types, called the semi-skeleton type, and so called because the skin of the leg guard joins each cane to the other but not continuously along its length.

Each component of a leg guard reproduces features and actions of its human counterpart. Thus, a cane is vertical as a bone of the lower leg is vertical; it is also about the same length as the bone. It helps to keep the leg guard erect and stiff, as a bone of the leg helps to keep the leg erect and stiff. The padding is springy or elastic like the flesh; and like the flesh can deaden the force of a blow; and its position relative to the cane is similar to the position of the flesh relative to a bone. The buckskin forms a covering for all the components of the leg guard as the human skin forms a covering for all the components of the leg. It helps to hold the components of the leg guard together as the human skin helps to hold the components of the leg together. It is evident that, unconsciously perhaps, makers of pads have reproduced several features of the batsman's leg by means of the leg guard, and have so made it that its actions also reproduce in a crude and elementary way the actions of a leg in stopping or deflecting a ball.

It would be fanciful to try and relate the structure and materials and actions of a cricket leg guard to the structure and materials and actions of a batsman's leg, if it were not for the fact that the structures, materials, and actions, of all mechanical implements can always be related to the structures and materials and actions of the machinery of the wielder's or user's body. It is not a fortuitous coincidence that the cricket pad reproduces so well so many of the features of the batsman's leg. It is rather an additional proof that the thesis of this work is correct, namely that a part of a weapon or other mechanical implement is a crude copy of a part of the machinery of the body.

The football is related to the foot, as the word football reveals; and becomes part of the foot when it is kicked and while it is in contact with the foot. A part of the foot is called the ball of the foot, and the phrase suggests the football is a mechanical extension of this part.

The phrase "ball of the foot" or "ball of the toe" is used to describe the rounded part of the foot at the base of the great toe. The exact limits of the ball of the toe however are difficult to determine; but certainly the volume of the football greatly exceeds that of the ball of the toe of any one player.

It has been shown by the author in a previous work that the football has the property of being able to represent all the players of a side to themselves and also to their opponents. It is also not always kicked by one person, and several players sometimes kick it at the same time; and in theory all are allowed to kick it simultaneously. It is therefore not essentially a one-man weapon or implement; but can be a weapon or implement to represent all the players either singly or collectively. In Association football there are twenty two players, eleven on each side; and possibly there is a relationship between the total volumes of the balls of the feet of the players and the volume of the football; but the author does not know for certain if this is so.

The Association football is approximately spherical, but the Rugby football approximately ellipsoidal. Reasons for the differences in shapes will be suggested when the football is again studied, with reference to the reproductive machinery of the body.

The football is related to the large hollow ball used in hand-ball or balloon-ball and also to the follis. Strutt writes, "The follis was a large ball of leather, blown full of wind, and beaten backwards and forwards with the fist, and seems to have been much played with . . . The balloon-ball, was a large ball made of double leather, which being filled with wind by means of a ventil, says Commenius, was driven to and fro by the strength of men's arms; and for this purpose every one of the players had a round hollow bracer of wood to cover

the hand and lower part of the arm, with which he struck the ball . . . The balloon-ball seems certainly to have originated from the hand-ball, and was, I apprehend, first played in England without the assistance of the bracer . . . " An illustration given by Strutt shows a player about to strike the ball with the bare and open hand.

Since the arm and hand are related biologically to the leg and foot, a ball can be related both to the hand and to the foot. The name hand-ball suggests the ball is related to the hand. A part of the hand is also called the ball of the thumb; and possibly the ball is an extension of this device, or because of its large size more probably is an extension of the balls of the thumbs of all the players.

CHAPTER 26

THE SPEAR-THROWER

A SPEAR is sometimes thrown with the help of a spear-thrower, which is a stick or wooden arm lightly attached during the throwing movements to the butt of the spear, the stick or wooden arm remaining in the hand when the spear has been thrown. The spear-thrower is found in Australia and in some islands in the Pacific and among the Eskimos and elsewhere, *Figure 27*.

The throwing-arm, when a spear-thrower is used, is formed partly by the arm of the thrower, and partly by the spear-thrower; and the arm of the thrower and the spear-thrower work together to throw the spear. The spear-thrower forms an extension for the arm, and increases the leverage it can exert and allows the power of the wielder to be more conveniently and effectively applied than when the arm alone is used.

FIG. 27.
AUSTRALIAN NATIVE WITH SPEAR-THROWER
J. G. Wood

Two main types of spear-throwers are used. In the first type, sometimes called the "male" type, a tooth or peg at the end of the spear-thrower fits into a hollow in the butt of the spear. Most Australian spear-throwers are of this type. In the second or "female" type, the connecting device is reversed, and the butt of the spear fits into a hollow or cup at the end of the spear-thrower. The two types are shown diagrammatically in

Figure 28. In *Figure 28* (*i*), the peg on the spear-thrower fits into the butt of the spear; in *Figure 28* (*ii*), the butt of the spear fits into the cup at the end of the spear-thrower. One device is therefore the reverse of the other (Rule 11).

There are many intermediate types between the male and female types of spear-throwers. These have been called by Krause " mixed " types. This class indeed " has the widest dispersion, being found among the north-eastern Asiatics, American Eskimos, in southern North America, in Central America, and one variety in South America; also very probably in France (during the reindeer epoch)."[1]

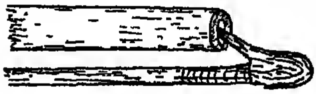
The right hand and fingers as they hold the "male" Australian spear-thrower make two devices or contrivances, one to hold the handle of the spear-thrower and one to hold the shaft of the spear. The shaft is surrounded or nearly surrounded by the forefinger or first two fingers, and rests on the tops of the remaining fingers. It impresses its shape on the inside of the forefinger or on the insides of the first two fingers and on the tops of the remaining fingers, and since it is approximately cylindrical, parts or bits of a cylinder are formed in the fingers to hold and partly contain the shaft of the spear. The parts of the cylinder thus made form a human barrel for the shaft. No breech is formed by the hand for the shaft, because the shaft does not lie in or against the palm.

The spear-thrower's grip is however held by the fingers and the palm; and is therefore provided with a barrel and a breech. The spear-thrower's grip is held by the palm and those fingers which are not placed round the spear's shaft. The barrel is formed by the fingers placed round or partly round the grip; and the breech is formed by the palm.

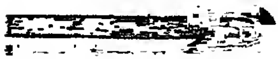
The reader can be reminded that the barrel of the offensive machine is always formed by the fingers, and the breech by the palm. This is true whether the machine is the

[1] F. Krause, Sling Contrivances for Projectile Weapons, in Annual Report of the Smithsonian Institution, June 30th, 1904, condensed from Schleudervorrichtungen Für Wurfwaffen, in Internationales Archiv. Für Ethnographie, Leiden, Band XV., Heft IV, 1902.

fist, claws, club, spear, sword, bow and arrow, rifle or atom bomb machine; but the barrel and breech, of course, can be given mechanical extensions. In the gun machine, for example, as will be explained more fully later, the barrel is given a mechanical or artificial extension by means of the metal barrel and the breech by means of the metal breech, breech block, and other devices. It can further be safely stated that it will never be possible to produce a serviceable weapon whose barrel and breech are not formed by the fingers and palm, or by the fingers and palm and mechanical extensions of them.



(i)



(ii)

FIG. 28.

DIAGRAMS OF SPEAR-THROWERS

(i) Male type
(ii) Female type

The fact that the barrel and breech are formed by the fingers and palm can be discovered by examining various types of the offensive machine like the thrusting spear machine and the bow and arrow machine. When this fact is known, the study of weapons becomes much simpler, because it merely becomes necessary when studying any particular variety of the offensive machine to notice how the weapon lies in the fingers and palm or is connected to them in order to discover how the barrel and breech are formed. Thus, in the present case, to discover how the barrel and breech of the spear-thrower machine are formed it is merely necessary to see how various parts of the weapon are held and supported by the fingers and palm.

There can be no doubt that the barrel and breech of the spear-thrower machine are formed by the fingers and palm, because this fact receives confirmation immediately the cup devices at the ends of the spear-throwers and shafts are studied, when it becomes evident that they are mechanical extensions of the barrel and breech formed by the fingers and

palm, and have many similarities of forms and shapes and actions to the barrels and breeches of guns, as will soon be shown.

The human part of the barrel of the spear-thrower machine, as has been pointed out above, is in two parts, one part being formed to hold and support the shaft and the other to hold and support the spear-thrower. Thus, supposing the forefinger only to be placed over the spear's shaft, the barrel for the shaft is formed by the inside of the forefinger and the top parts of the remaining fingers; and the barrel for the spear-thrower by the insides of the fingers whose top parts help to form the barrel for the shaft. A breech for the spear-thrower is formed by the palm, but a breech is not formed by the hand for the shaft.

Parts of the interior surface of the human barrel are therefore formed by the fingers on which the spear shaft presses. Usually, the interior surface of the human barrel of a weapon is formed by the insides of the fingers. It is formed by the insides of the fingers, for example, when a club, spear, javelin, or sword is held. The reverse sides of some of the fingers however are used to form the interior surface of the barrel for the spear shaft of the spear-thrower machine.

A glance at *Figure 28* (*ii*) will show that the cup device at the end of the spear-thrower, in which the butt of the spear rests, is a crude mechanical reproduction of the pouch, or cup-like device which the hand forms as it holds the handle, transferred to the end of the spear-thrower. The right hand cannot hold the spear's shaft at a distance from its butt and at the same time form a cup device to enclose its butt; but by transferring a mechanical copy of the cup device to the end of the spear-thrower, the middle of the shaft and the butt can be held simultaneously. The butt is held in much the same way by the cup of the spear-thrower as it would be held if the hand were placed round the butt to throw the spear; and the cup device of the spear-thrower is merely an artificial and distorted copy of the cup device formed by the pouch which holds the handle of the spear-thrower. It is therefore a mechanical reproduction of the barrel and breech formed by

the hand transferred to the end of the wooden spear-thrower.

In *Figure 28* (*ii*) the butt of the spear fits into the cup device of the spear-thrower. The type of fitting in *Figure 28* (*i*) is nearly the reverse of that in *Figure 28* (*ii*), for in *Figure 28* (*i*) instead of the spear shaft fitting into a cup device on the spear-thrower, the spear-thrower fits into a cup device at the butt of the spear. It was explained in the preceding paragraph that the cup device is a transferred mechanical copy of the cup device or pouch formed by the hand which holds the handle. Therefore the little cup device in the butt of the Australian spear-thrower must also be a transferred mechanical copy of the pouch or cup device of the hand holding the handle of the spear-thrower.

The peg or tooth of the Australian spear-thrower which fits into the cup or socket in the butt of the spear is a mechanical extension of a bent forefinger. If no spear-thrower were used, the spear could be thrown somewhat after the manner in which it is thrown by a spear-thrower, either by the right hand forming a cup for the butt end or by the forefinger or first fingers being placed against the butt end or in a socket in the butt end. The advantage of increased leverage given by use of a mechanical spear-thrower would however be lost, and the spear could not be thrown very effectively by either of these methods, but the actions of throwing with a spear-thrower could be fairly well reproduced. Probably therefore the peg or tooth is a mechanical reproduction of a forefinger or of the first few fingers formed into a device suitable for placing against the butt of a spear or into a socket in the butt of the spear to drive it forward. In *Figure 28* (*i*) indeed the tooth or peg does have some resemblances to a bent forefinger, and can easily be recognized as a crude mechanical copy of the offensive device formed by a bent forefinger.

The reader can easily discover for himself and form the prototype of the spear-thrower with the help of say a broom handle. If the broom handle is placed along the arm and its butt is held in a cup formed by the hand and fingers of that arm, the female spear-thrower's human prototype will be formed by the wielding arm and hand. If instead of making

a cup to receive and hold the butt of the broom, the forefinger is placed against its end or in a socket in the butt end, the male spear-thrower's human prototype will be formed. The broom handle can be thrown either with a thrust from the base of the cup or with a thrust from the forefinger along the direction of the handle.

The spear is drawn back by the fingers, but the fingers play little direct part in drawing it forward. It is driven forward directly by a thrust from the cup or peg of the spear-thrower. Indirectly and primarily, of course, the spear is driven forward by the fingers, but they act only through the agency of the spear-thrower.

The barrel for the spear's shaft is not formed solely by the fingers placed round the shaft. A transferred mechanical extension of the human barrel device, in the form of a wooden cylinder surrounding the butt is formed by the sides or rim of the cup. The barrel is therefore in two parts. A human part is formed by the fingers, and a mechanical counterpart by the sides of the cup. The human and mechanical parts are separated by the distance between the fingers and the cup. The barrel is not continuously formed, and is formed at its fore part only by the fingers, and at its end by the cylindrical part of the cup. By transferring a part of the barrel to the butt, good control is obtained by the barrel over the shaft, which could not be obtained if the shaft were held only at the middle.

Since a mechanical part of the barrel is formed by the cup of the female spear-thrower, part of the barrel of the male spear-thrower machine must be formed by the cylindrical part of the cup device in the butt of its spear. The cup device of the male spear faces the opposite way to that of the female spear-thrower, for the mouth of the male cup faces away from the point of the spear but that of the female cup faces towards the point. In one variety of the spear-thrower machine, therefore, the direction of the cup is reversed compared with its direction in another variety (Rule 11). Also, since the cup in each variety is a mechanical form of the breech, the mouth of the breech of the female spear-thrower

machine faces the direction of the motion of the missile. This is similar to the direction of the breech of the gun machine whose mouth faces the direction of the missile's motion. But the mouth of the breech of the male spear-thrower machine faces away from the direction of motion of the missile. A mechanical breech can therefore face the opposite way to the direction of motion of the missile.

When an Australian spear-thrower is used, the spear is held and thrown in much the same way as the javelin is held and thrown. There are many ways of holding the javelin, different wielders preferring different types of grips. The javelin however always lies in the palm of the hand; and usually two or more fingers are placed round the shaft, and the thumb and forefinger lie along the shaft in a line with the arm and pointing towards the butt of the shaft. The little finger sometimes is folded back and points towards the arm and point of the javelin. The thrust is given immediately and directly by the fingers and thumb and hand, the forefinger especially playing an important part in thrusting the javelin forward. The thrust forward when the spear-thrower is used is not given immediately and directly by the human fingers and thumb and hand, but by their mechanical counterparts which are at the end of the spear-thrower in the forms of the peg and socket. The peg releases the fingers, and the socket releases the hand, from the work of directly thrusting the spear forward; and the peg and socket thrust the spear forward in much the same way as the fingers and thumb and hand thrust the javelin forward.

The wielder of an Australian spear-thrower has some advantages over the javelin thrower, one being that the mechanical finger, or peg, fits into a socket and has a firmer grip of the spear than the fingers of the javelin thrower have on the javelin, and although some help in obtaining a grip can be obtained from the binding, the grip for a thrust forward is not so good or easy as that obtained by means of a peg fitting into a socket.

Release of the spear is effected by its passing beyond the reach of the fingers, and by the separation of the socket or

peg and end of the spear which occurs automatically as the butt passes out of reach of the socket or peg. The fingers must straighten and relax at the moment of throwing or the spear shaft will be dragged down and the aim be upset.

The butt of the spear is not always placed in the cup of the spear-thrower. Sometimes the tooth or peg which is placed in the cup is fastened to about the middle of the spear's shaft. The thrust is then applied at the middle of the shaft instead of at the butt. The tooth or peg can be transferred from the butt to the middle, because the shaft really consists of two arms placed end to end, and a tooth or peg transferred to about the middle is transferred from one end of an arm to its opposite end.

The devices formed by the fingers to hold the grip of the spear-thrower are sometimes partly mechanized. The grips of Australian spear-throwers often have indentations or notches for the fingers, or are wrapped with hair or covered with rosin in which a shell or stone is often stuck to make a firm grip easy. The grips of Eskimo spear-throwers may have a hole in which the forefinger is inserted, or one or more pegs project from the border of the grip, against

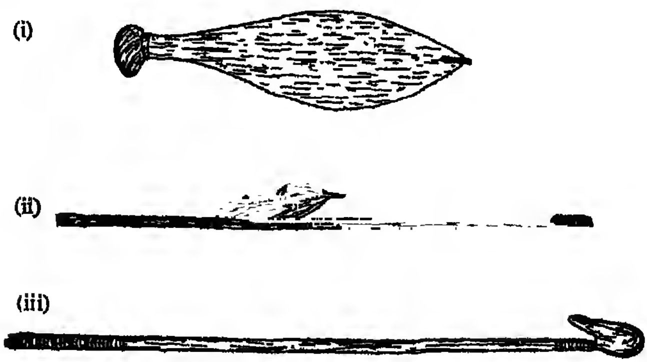


FIG. 29. SPEAR-THROWERS. *Horniman Museum*
(i) Australian, with lump of gum on handle
(ii) Northern New Guinea
(iii) Australian

which the index and other fingers rest. A New Guinea spear-thrower has a complicated extension projecting near the grip. Catches, clasps, grooves, projections and other devices, are formed by these special grips to assist the fingers in holding the spear-thrower and spear shaft. Thus, for example, a New Guinea spear-thrower of the female class is made from a bamboo cane. It ends at a joint which is hollowed out to receive the spear. A complicated contrivance is fastened to the spear-thrower, and is placed against the side of the spear. According to Krause, "the right side of the spear leans against the attached piece, where it is tightly pressed with the thumb, the fingers clasping the grip, the attached piece here taking the place, so to speak, of fingers (V. Luschan)." The piece forms an artificial extension for the fingers, and releases them from the work of directly holding the spear's shaft.

Sometimes the left hand of the wielder is also placed on the shaft, although it is removed just before throwing the spear. The barrel when the left hand is holding the shaft is directly formed by both hands and by the mechanical extension of the barrel of the right hand. After the left hand is removed it still forms part of the barrel, but not directly for it is not then in actual contact with the shaft. It is clear however that the spear-thrower machine has an extensible barrel, for the distance between the hands varies as the weapon is being wielded. The barrel is probably of minimum length when the left hand is on the shaft, and of maximum length when the spear is released from the spear-thrower.

The female spear-thrower machine and the caber tossing machine resemble each other in many respects. Both machines throw a spear type of missile, but the caber machine's missile is very much greater in diameter than that of the spear-thrower machine's missile. Compared with the caber the spear is turned through a right angle (Rule 10), for the spear is held horizontally but the caber vertically, or more correctly, the spear is held at right angles to the stock of the body but the caber is held parallel to it. The spear-thrower for the caber machine is formed by the tosser's arms, and is human. The caber's butt rests in a cup formed by the tosser's

hands and fingers: the spear's butt rests in a cup formed by a transferred mechanical copy of the wielder's hand and fingers. The cup device of each machine forms its breech and back part of the barrel. The fore part of the barrel of each machine is at some distance from the butt of the missile. The caber's fore part is formed at the shoulder, but the spear-thrower's fore part at the end of the arm opposite the shoulder (Cp. Rule 8). When a cloth is at the shoulder, the fore part of the barrel of the caber machine is mechanized, but the back part and breech are human: conversely, the fore part of the barrel of the spear-thrower machine is human, but the back part and breech are mechanized (Rule 11).

Many of the directions of the actions of one machine compared with those of the other machine are turned through a right angle. Thus, the arms of the caber tosser give an upward heave, but the arm of the wielder of a spear-thrower gives a horizontal pull to propel the missile. The caber moves at right angles to the axis of the fore part of its barrel, but the spear moves along the axis of its barrel. The caber is spun about an axis which is at right angles to the direction of its barrel, the spear about the axis of its barrel.

It is clear the essential mechanisms and actions of the caber machine and the spear-thrower machine are the same, and one machine is merely a modified form of the other.

The effects obtained by means of a spear-thrower can be obtained very nearly by means of a throwing-string, the spear-thrower being a mechanical extension of the rigid components but the string being a mechanical extension of the flexible components of the wielding arm.

A spear is sometimes thrown with the help of a thong fastened to the spear usually at about its middle by a binding similar to that on a javelin, the forefinger, or the first two fingers, being placed in a loop of the thong, and the spear being held by the remaining fingers of the throwing hand.

The barrel for the spear thrown with the help of a thong is in two main parts. A human part is formed by the fingers placed round or partly round the shaft, and a mechanical or artificial extension is formed by the turns of the thong

which surround the shaft at about its middle. The human part is usually a little in front of the mechanical part, and does not surround the mechanical part as in the javelin machine in which the fingers are placed on the whipcord binding. The pouch, or breech, is human, and is formed by the palm of the throwing hand, and is a continuation of the human part of the barrel. The final thrust to drive the spear forward is given directly by the thong attached to the forefinger, which acts as a mechanical extension for it; but of course indirectly the forefinger gives the thrust. The forefinger placed in the loop forms a device somewhat resembling the peg of an Australian spear-thrower, and acts in much the same way, except that the forefinger's action is applied at the middle of the shaft, by way of the loop, but the peg's action is applied at the butt of the spear. In the Australian spear-thrower machine the forefinger device, as has been explained, is transferred to the butt as a mechanical device in the form of the peg.

At the moment of release, the fingers placed round the shaft relax and straighten, and the forefinger also at the same time relaxes and straightens and points in the direction the spear has gone.

The loop of the thong acts as a mechanical extension of the forefinger device, and by means of it the actions of the forefinger are continued and extended. If two fingers are placed in the loop, it acts as a mechanical extension of the device formed by the two fingers. When the thong is not fastened to it but merely wound round the shaft, the loop is retained by the forefinger, or first two fingers, and the shaft is made to spin by pulling on the loop as the shaft leaves the hand. As the shaft spins, the thong unwinds, and the rifling device formed by its turns comes into action, and thus reveals that the spiral groove between the turns is really a rifling device; although it may not be directly used, as for example when the binding is fastened to the shaft as on the modern athletic javelin. As the binding unwinds, the mechanical part of the spinning device is transferred away from the fingers to the parts of the thong wound round the shaft, and the fingers do

not then directly spin the spear, but spin it indirectly through the agency of the thong.

A spear is sometimes thrown by the ounep, which is a piece of rope with a knot at one end and a loop for the finger at the other, *Figure 30* (*i*). The ounep used in Melanesia is about nine inches long. It is lightly attached to the spear by

(i)

(ii)

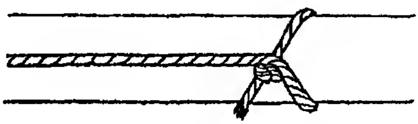


FIG. 30.

(i) Ounep, *Pitt Rivers Museum*
(ii) String attached to arrow

a becket, which is a knot made by the string passing once round the shaft and hooking itself behind the knot so that as the shaft goes forward it easily disengages itself from the shaft. Darts and arrows are thrown by boys in civilized countries by means of a string with a knot at one end, the string resembling the ounep but being longer and thinner.

The fingers placed round the shaft form a human part of the barrel. A mechanical part is formed by the single turn of the ounep placed round the shaft a few inches away and secured by the becket. The part of the ounep which passes round the shaft takes the form of the shaft and forms a type of mechanical barrel similar to that formed for a modern javelin by the whipcord binding but consisting of only one turn. It is thus a very short cylindrical mechanical barrel, and since it is made by only one turn a spiral rifling appears only as a fragment where the knot meets the string passed round the shaft. The breech is formed by the hollowed palm.

It is human, and a continuation of the human barrel formed by the fingers placed round the shaft.

The thrust is given by the forefinger and ounep, the ounep forming a mechanical extension of the forefinger device. When a dart or an arrow is thrown by a string the mechanical extension is longer and thinner, *Figure 30* (*ii*).

The rifling device is sometimes formed for the boy's arrow or dart by a piece of square paper folded and placed in the split butt so that four paper "feathers" project. The paper feathering is not placed spirally, and does not help to spin the missile but keeps it true in flight.

When a spear-thrower is used, as has been said, the rigid or hard components of the wielding arm are partly mechanized by means of it. The wielding arm, however, is not made entirely of hard parts, but contains also soft and flexible parts. An ounep or throwing string probably is a contrivance which imitates the contrivance formed by the tendons, sinews, and similar cord-like components of the wielding arm, and becomes an extension of them capable of working in harmony with them. The human strings are contained within the arm, and are not visible, and we are not familiar with their appearances and actions; and the mechanical string cannot therefore easily be recognized as corresponding to the human strings. Also, correspondence is difficult to observe because the mechanical string is a very crude and imperfect reproduction of the complex string devices of the wielding arm.

Chapter 27

THE SLING

A COMMON type of sling consists of two strings fastened to a pouch. It is whirled two or three times either round the head in a plane inclined to the horizon or in a vertical plane at the side of the body. At the right moment one of the strings is released to throw the missile. The strings form flexible extensions for the arm or arms and allow a greater leverage to be exerted on a missile than when one is thrown by the unmechanized arm.

Fig. 31.
(i) Slinger; Colonna Trajana, Bartoli
(ii) Sling bullet; W. Hawkins, Esq., F.S.A., *Archæologia,* Vol. XXXII, 1847.

The pouch is often made of leather or skin. The strings are made of hemp, skin, leather, sinews, plaited grass, or other materials. The pouch of the Tierra del Fuego sling is made of seal skin or guanaco skin, and its cords are made of twisted sinews. The strings of the Sandwich Island sling are very long, and its pouch is made of matting. The New Caledonian sling, or wendat, has a pouch made of two small cords laid side by side.

The missiles are usually between $1\frac{1}{2}$ and $3\frac{1}{2}$ ounces in weight, and ovoid in shape. The New Caledonian stone is ovoid and made from steatite carefully ground to the required shape. The Sandwich Island stone is also ovoid.

One type of Sandwich Island sling has the pouch transferred to the missile, a groove being cut round the stone to receive the cord. The stone is made of haematite, or blood stone, and some of the stones obtained by Captain Cook were very heavy, weighing at least a pound. The missiles of the Romans were shaped like acorns, and called by them, glandes (acorns); the name used by the Greeks for their missiles was σφαιραι μολυβδιναι (leaden balls).[1] An ancient Greek sling missile is shown in *Figure 31* (*ii*).

The mechanical pouch of the simple sling holds the missile in much the same way as the hand holds the shot or cricket ball or stone. The shape of its interior corresponds to the shape of the missile, whatever the missile's shape, for centrifugal force causes the missile to press against the pouch and its shape is then faithfully reproduced on the inside of the pouch.

To aim the missile, when the sling is to be whirled round the head, the slinger holds the pouch with his left hand stretched forward in front of his head, and the string ends with his right hand above and behind his head. The strings are made taut and held along the direction of the proposed throw, and inclined to the horizon at the necessary elevation. The left hand is then suddenly removed from the pouch and the right hand whirls the sling round and above the head. The left hand is not held stationary, but is moved in a plane below the one in which the right hand is moved. Its movements appear to be opposite to those of the right hand. One of the ends of the strings is lightly attached to the forefinger or first two fingers so that it can be easily released, and the other is fastened to the remaining fingers or fingers and hand.

During the aiming movements, the missile is held mainly by a contrivance formed by the leather pouch and left hand, the contrivance being partly mechanical and partly human. It is held also partly by the right hand, for the right hand holds the strings tight and helps to hold and control the left hand and missile. During the whirling movements when the sling is being held by the right hand, the missile is held by

[1] W. Hawkins, Esq., F.S.A., *Archaeologia*, Vol. XXXII, 1847.

the pouch; but the right hand forms a complementary part of the pouch, for it still forms a kind of pouch as it holds the strings, and opens when the pouch opens to release the missile. The left hand also helps to control the missile, for it helps to balance and control the right hand; and its movements are very similar to those of the right hand. The missile therefore although thrown directly by one hand only is indirectly thrown by both hands. Release is effected by straightening the forefinger, or fingers, and releasing the lightly attached string end, and by the opening of the pouch; the straightening of the forefinger, or fingers, and the opening of the pouch occurring at the same time.

A sling may be made of a continuous piece of material, or the pouch and strings may be made separately and then be joined by fastenings. The fastenings correspond to the fastenings holding the hand to the arm; and they are transferred with the pouch to the ends of the strings opposite the hand (Rule 8). The mechanical pouch can be easily recognized as corresponding to the human pouch made by the hand when it holds a missile like a shot or cricket ball; but the mechanical fastenings joining the pouch to the strings cannot be so easily recognized as corresponding to their human counterparts, for their human counterparts are not exposed to view and we are unfamiliar with their appearances and actions, and the mechanical fastenings are merely crude and imperfect copies of the human fastenings.

The pouch of the sling machine is not fully mechanized, for the leather pouch is merely a crude mechanical reproduction of the pouch formed by the right hand as it holds the strings, transferred to the ends of the strings opposite the hand. The complete pouch is formed by the human pouch of the right hand and the mechanical counterpart, or leather pouch.

Correspondence of materials is fairly close when the pouch is made of skin, for the skin of the pouch then reproduces the skin of the hand fairly well. It is less close when the pouch is made of leather or matting. Correspondence of the sling strings to the strings of the arm is probably fairly close

when they are made from sinews, and less close when made from leather or hemp or manufactured materials.

The leather pouch copies fairly well the shape of the interior of the pouch of the hand; and is a mechanical type of breech. But by means of it the barrel is also partly mechanized, for when the sling is being aimed the left hand fingers grip the sides of the pouch, and the barrel is then formed mainly by the left hand fingers and sides of the pouch. A human part of the barrel is then formed by the fingers and a mechanical part by the sides of the pouch. When the sling is being whirled the fingers are not in contact with the sides of the pouch; but the barrel is still formed partly by the sides of the pouch, which then act as a mechanical counterpart of the barrel formed by the right hand fingers at the other end of the strings, the barrel device formed by the right hand fingers being partly transferred in the form of the mechanical device, formed by the sides of the pouch, to the opposite ends of the strings.

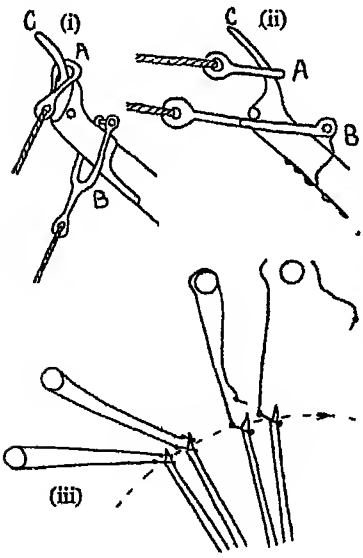


FIG. 32.
ACTIONS OF THE TREBUCHET
After Viollet-le-duc

The strings when the sling is being whirled act as mechanical extensions for the strings of the right arm, but after release of the missile they tend to come into a straight line and then perhaps become mechanical extensions of both arms. But perhaps they are at all times mechanical extensions of the strings of both arms, but placed side by side until the missile is released.

Mechanical string ends with their mechanical fastenings

and attachments can be seen on the trebuchet, which was an engine of war used in ancient and mediaeval times, *Figure 33.* The trebuchet had a long arm to the end of which a sling was fitted. The arm was moved by means of counterweights sometimes weighing several hundredweights, and was wound down by levers or pulleys. The missile varied, but was usually a round stone. The methods of fitting the strings, which are represented by the ropes of the sling, to the arm are shown in *Figure 32* (*i*). The lower metal loop B, Figure 32 (i), is fastened to the arm; the higher loop A is lightly attached to the metal finger C so that when the arm is at about the highest point in its revolution it is automatically cast off to release the missile. In *Figure 32* (*ii*) the arm is shown in another position with the loop A about to slip off the finger C. The metal finger C is not flexible, and cannot bend as the human finger can bend; but it has a recognizable resemblance to a forefinger. Release is effected by mechanical means, centrifugal force pulling the loop A off the finger at the right moment. *Figure 32* (*iii*), shows the trebuchet's arm and sling in different positions during the arm's revolution and shows the strings being released and the missile being thrown; and it can be seen that the actions of the human slinger's arm and fingers are approximately reproduced by mechanical means.

Although the finger of the trebuchet cannot bend, the action of straightening the finger to release the string end is reproduced, for during the throwing movements the metal finger is too much inclined for the metal loop to slip off; but at the moment of releasing the missile the finger is inclined in the direction of the target sufficiently for the loop to slip off. The straightening of the finger to release the missile is therefore performed although the finger cannot bend.

Drawings of trebuchets and other ancient and mediaeval engines of war may be seen in works by Valturius, Viollet-le-duc, Napoleon III, Grose, Cowper, and others. In his work on the crossbow, Sir Ralph Payne-Gallwey has drawings of trebuchets, catapults, and ballistas, which he has reconstructed. Figure 33 is a rather fanciful sketch of a

trebuchet according to Valturius, the military historian, A.D. 1472, showing the arm, counterweights, strings, pouch and missile, and method of fitting the strings.

The fastenings which join the ends of the strings of a sling to the hand are partly mechanized, for mechanical clasps are formed by the turns of the string ends as they surround the fingers, and grooves are formed by the strings in the skin and flesh of the fingers. As the strings are being whirled. the string ends tighten round the fingers, and the skin and flesh grooves become deeper. The human grooves are complementary in shapes to the shapes of the clasps, and the strings fit into the grooves they make. The actions of the devices formed by the strings and the human grooves are also complementary, but are difficult to study.

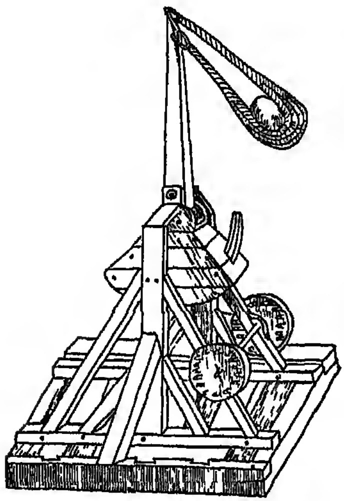


FIG. 33.
TREBUCHET
Valturius

The clasps formed by the end of the string which is set free are differently formed from those formed by the end which is retained, and types of clasps are formed by the lightly attached string which can easily and suddenly be undone to allow the string to leave the forefinger or first two fingers. The differences in types is clearly shown in the two different types formed for a trebuchet, one string end being permanently secured to the trebuchet's arm, and the other being lightly attached so that it can easily slip off at the right moment. The string ends for a trebuchet are crude copies of those formed by string ends fastened to the hand, and reproduce only certain of their features and actions,

although essential features and actions are reproduced. Fastenings which hold string ends to bows are types of the fastenings made when sling ends are held by the fingers.

The magazine of the sling machine is partly mechanized when the slinger carries spare missiles in a bag or other contrivance. When the release action of the hand and fingers is not used, the wielder can easily repeat the movements of hitting the opponent. Thus, the fist or club or spear or sword can be drawn back when a blow or thrust has been given and the hitting or thrusting actions and movements can then be repeated. But when the release action is used, and the weapon or a part of it is thrown, the wielder must perform many actions and movements before another blow or thrust can be given. Before the shot or javelin or caber thrower can throw again he must retrieve his missile or obtain a new one, and his actions and movements when retrieving a missile or obtaining a new one are complicated and cannot easily be analysed. Information about the actions and movements that take place between the throws can most easily be obtained when there are some mechanical parts to perform some of the repeating actions and movements. Part of the repeating machinery of the slinger is mechanized when he carries spare missiles in a bag slung over his shoulder or at his side, or in the folds of the outer dress, *Figure 31* (*i*). The bag or fold of the dress is a mechanical or artificial contrivance which is of help in the repeating actions and movements, and is a mechanical part of the repeating machinery of the slinger. But the mechanical part of the repeating machinery is in a rudimentary stage of development, and human actions and movements are needed to place the missiles in the bag or fold of the dress and to take them out and to fit them to the pouch of the sling.

The sling has various forms. The cleft stick is a type of sling. It consists of a stick cleft at one end to receive a flat stone, *Figure 34* (*i*). The throwing-arm of the wielder of a cleft stick is formed partly by the arm of the wielder and partly by the stick; and the arm and stick work together to wield the cleft end and to throw the stone. The

stick forms an extension for the throwing-arm, and increases the leverage it can exert. The weapon is held and controlled

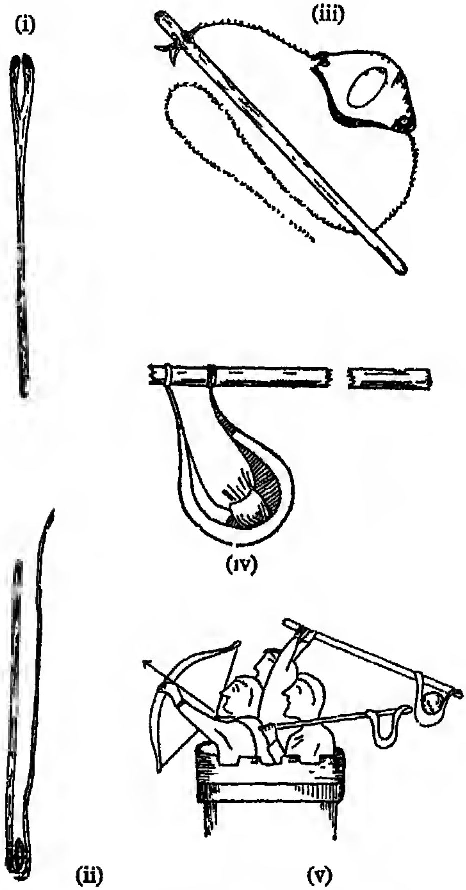


FIG. 34. STAFF SLINGS

(i) Cleft stick
(ii) Staff and strap
(iii) Staff sling, XVth Cent., *A. Demmin*
(iv) Staff sling, from XVIth Cent. M.S., *A. Demmin*
(v) Staff slingers, from XIIIth Cent. M.S., *J. Strutt.*

by the hand which holds the stick. The missile is held and controlled directly by the cleft end, and also indirectly by the

hand holding the stick. The cleft end has a rudimentary resemblance to an outstretched hand and thumb and is a crude mechanical form of this device transferred from the lower end of the stick to the other end. It releases the hand and thumb from the work of directly holding and releasing the missile; but it is too imperfect a form of the throwing hand for the cleft stick to be a very effective weapon.

Another type of sling has a staff to one end of which a strap is fastened, the strap being about equal to the length of the staff, *Figure 34* (*ii*). A flat missile is held by the rude pouch formed at about the place where the staff and strap join. The free end of the string, or strap, is lightly attached to the hand; but the other end is transferred to the end of the staff opposite the hand; and the staff holds the string end, and releases the hand from the work of directly holding it.

The staff and strap are side by side during the wielding movements, that is, the mechanical extensions of the rigid and flexible parts of the arm or arms are side by side; but after the strap is set free, it extends outwards from the end of the staff, and tends to come into line with it. The pouch is very crudely formed. Release of the missile is effected partly by straightening the finger or fingers holding the strap, and partly by the opening of the pouch, the finger or fingers straightening and the pouch opening at the same time.

Another type of sling has a staff with two strings, one string being shorter than the other. The strings are joined to a pouch, and the shorter string is fastened to one end of the staff, *Figure 34* (*iii*). The staff and strap sling described above has only one string; but the sling now being described has two strings, but one of them is imperfectly mechanized. The shorter string is fastened to the end of the staff opposite the hand, and the end of the staff releases the hand from the work of directly holding it. The missile is held partly by the pouch; and also partly by the hand holding the string end, and partly by the end of the staff holding the shorter string for the pouch cannot contain the missile if the hand releases its string end, as it does when the missile is being

released, or if the fastenings at the end of the staff come undone. The human part of the pouch for the missile is therefore formed by the hand holding the staff and string end; and the mechanical parts partly by the pouch between the strings, and partly by the end of the staff holding the shorter string. Release is effected by straightening the finger or fingers holding the lightly attached string, and by the opening of the pouch, the straightening of the finger or fingers and the opening of the pouch occurring at the same time.

The staff sling consists of a heavy staff, from four to six feet in length, with a pouch slung at one end. The end of the pouch nearer the hands is fastened to the staff, but the other end is lightly attached by means of a ring resting in a slight groove, *Figure 34* (*iv*). To throw the missile the staff is held in both hands and is brought up from behind the middle of the back over the head, *Figure 34* (*v*). In olden times the missile was often a grenade. Both arms take an active part in wielding the staff, and the throwing arms are formed partly by the human arms and partly by the long and heavy staff which forms an extension for the arms. The hands are released from the work of directly holding the pouch and releasing the missile; but they must bring the staff into the position in which the ring can slip off to allow the pouch to open and release the missile. The missile is therefore only partly held and controlled by the mechanical pouch. The ring corresponds to the fastenings which hold the lightly attached string to the fingers of the simple sling, and is another mechanical form of the fastenings. The strings are imperfectly mechanized, and may be represented by the parts of the pouch which join it to the staff and to the ring. The end of the staff holds and releases the ring in much the same way as the finger of the trebuchet or the forefinger of the wielder of a simple sling holds and releases the lightly attached string, and the end of the staff is therefore another mechanical form of the forefinger or forefingers, but is a more rudimentary form than the trebuchet's finger, and is transferred from the hands holding the staff. The staff sling

is uncertain in its actions and is not a very effective weapon.

Other types of slings are the athletic hammer and weight, which have been studied in a previous chapter.

Chapter 28

THE BOW

It has been pointed out that the typical club somewhat resembles a fist at the end of an arm, for the reason that it is a mechanical or artificial copy of the offensive contrivance formed by a fist and arm. Similarly, the typical spear, which is a spear with a leaf-shaped blade, somewhat resembles a hand at the end of an arm, for the reason that it is a crude copy of a thrusting weapon that could be formed by a hand and arm. The croquet mallet resembles a leg and foot, because it is a mechanical copy of the leg and foot. The lawn tennis racket resembles a hand and arm, because it is derived from the hitting implement formed by a hand and arm. Indeed each weapon or implement that has been studied resembles some human contrivance, for the reason that it has been derived from and is a crude copy of the human contrivance.

But the weapons that have been studied have consisted of only a few parts and devices. More complex weapons are now to be studied, and the form of the human body, as might be expected, will begin to be more clearly and fully reproduced by the weapons. Thus, for example, if a cross-bow is placed upright, the form of the human body with arms outstretched can be distinctly seen. The human arms are represented by the bow arms, the stock of the body is represented by the wooden stock of the weapon, and so on, (see Figures 39, 54, 63). The human form is foreshadowed in the ordinary bow and arrow; and if an arrow is laid on a bow and the weapon is placed upright, the form of the human body can be distantly seen. But the significance of this foreshadowing of the body by a weapon cannot be fully understood until weapons are studied with reference to the reproductive machinery of the body, as will be done in Part II of this work. In the meanwhile, it can be noticed the

bow arms correspond to and reproduce the outstretched human arms, and the strings reproduce the strings of the human arms. The ordinary bow and arrow has no mechanical stock; and the stock of the bow and arrow machine is human, and formed only by the body of the wielder of the weapon.

If the ends of a sling are held, one in each hand, and the arms are opened out until the strings are nearly in a straight line, the form of the pellet bow will be seen. The wooden limbs or arms of the pellet bow correspond to the human arms; the handle of the bow, or part held by the left hand, corresponds to the parts of the chest between the arms; the bow nocks correspond to the hands; and the strings correspond to flexible parts of the arms. The actions of the pellet bow can be reproduced approximately, for if the strings are held as before and the body is bent until the sling's pouch just rests on the ground and the arms are suddenly extended, the missile will be thrown in much the same way as from a pellet bow. The experiment would be dangerous, of course, for the missile might be thrown at the face or chest. The target would be behind the thrower, and aiming would be difficult.

In the experiment, the missile would be propelled to the rear instead of to the front of the thrower, the direction of the missile thus being exactly reversed compared with its direction when a pellet bow is being wielded, in accordance with Rule 11.

When a pellet bow or an ordinary bow and arrow is being wielded, its arms * are reversed compared with the arms of its wielder, for the concavity of the wielding arms is towards the bow but the concavity of the bow is towards the body, the concavity being reversed in accordance with Rule 11.

The upper limb or arm of the ordinary bow corresponds to and is a crude mechanical reproduction of the right wielding arm, if the wielder shoots right handed; and the lower

* H. Balfour defines the arms of a bow as, "The flexible portions lying between the central "grip" and the rigid extremities."—*The Journal of the Anthropological Institute,* Vol. XIX., 1890.

limb or arm corresponds to the left wielding arm. This is evident because the upper bow arm is often made a little longer and more flexible than the lower bow arm. According to James Duff, a maker of bows and a writer on the subject of making them, "the lower limb of the bow should be made shorter than the upper one and should be stiffer"[1]; and since the left arm of the archer is stiffer and less flexible than his right arm (if he is right handed), because it is not so practised, it is clear that the upper bow arm corresponds to the right arm and the lower one to the left arm.

It is sometimes said that the length of a bow should be governed by the height of the user; and the length of the long bow was indeed supposed to be the same as the height of its wielder. But the height of a person is approximately the same as the distance between his outstretched hands measured from the ends of the fingers of one hand to the ends of the fingers of the other hand. Therefore the length of the bow is governed, as might be expected, by the lengths of the arms and width of the chest. According to James Duff, the length of the bow should be governed not by the height of the archer but by the length of his arm, — "the length of the bow should be governed by the length of the arm of the shooter in drawing his arrow to its head — a rule the professional maker always has recognized."

Although the length of the bow is related to the length of the wielder's arms, yet distortion may make correspondence difficult to observe. Thus the pygmy Andaman Islanders use bows sometimes seven feet in length; but the Bushmen of South Africa and the Red Indian horsemen have very short bows. Sometimes reasons for distortion are evident. Thus, for example, the Bushman of South Africa uses a small and weak bow, seldom more than four feet long and often less, and it is so poorly made that any little boy can make with a stick and a string a bow quite as good. But the Bushman cares little about its strength or accuracy of aim, inasmuch as he seldom shoots at objects more than a few yards away and likes to creep to within eight or ten

[1] *A Practical Book on Making Bows and Arrows.*

yards of his target if he can do so. It is said that in a test a Bushman failed to hit an antelope skin nearly seven feet square hung on a pole at a distance of twenty yards, though he hit it with his second shot.[2] The Bushman, however, is a deadly enemy to game or man, because his arrow which is only about eighteen inches long and unlike the bow is well made, is poisoned, and provided he can make it scratch his quarry, he kills it. Since the full power of the body is not used by the Bushman archer, it cannot be expected that his bow will show much correspondence in length or power to the length and power of his arms and body. One of the most famous bows, the long bow, however, it can be noticed again was very closely related in length to the length of the archer's arms; but the archer "laid his body in the bow" and used his full strength in harmony with that of the bow.

The upper and lower bow arms are connected by the handle; and the bow thus consists of three main parts, the upper arm, the lower arm, and the handle or part between the upper and lower bow arms. The limits of these parts cannot easily be known when the bow is made from a single piece of wood. Certain types of bow arms, however, are made separately from the handle, when it becomes easy to distinguish the different parts. Modern bows, for example, are sometimes made in three sections, for convenience in transport, and fitted together in much the same way as parts of a fishing rod are fitted together. The three parts of the bow can be distinctly seen in the catapult with elastic strings used by boys, the two arms being the forks to which the strings are fastened, and the handle the part held by the hand. The toy catapult is a diminutive type of bow.

The handle of the bow connects the bow arms. The wielder's arms are connected by devices formed by his chest. Therefore the bow handle must correspond to the human devices which connect the arms of the wielder of a bow. Although these human chest devices are partly mechanized and externalized by means of the bow handle, it is not

[2] The Rev. J. G. Wood, M.A., F.L.S., etc., *The Natural History of Man.*

possible to discover much about the human devices. It can be observed that the bow handle joins the bow arms; keeps them at a certain distance apart; and so on. Presumably the human devices act in a similar way to join the wielding arms, to keep them apart, and so on. A considerable difficulty however arises when trying to relate the chest devices and the handle device, because the handle, as will soon be seen, is not merely an extension of the chest devices but is also a mechanical extension of the barrel of the hand, of devices holding the chest to the arms, of the elevating devices, and of many other devices; and it is not easy to see these devices separately in the bow handle. Therefore, at least for the present, we must be content with noticing that the handle is a mechanical extension of the chest devices without being able to say much more that is useful about the way the chest devices are formed.

The bow handle is held by the left hand, with the left arm stretched forward, *Figure 35*. It is therefore a mechanical reproduction of the chest device transferred from the chest to the end of the left arm. Presumably the human device is horizontal, and when the bow is held horizontally, as it is held for example by the Bushman of South Africa or the Eskimo, the mechanical counterpart when transferred remains horizontal. But when, as is usual, the bow is held in a vertical plane the handle is turned through a right angle, (Rule 10). The bow arms themselves are transferred from the wielding arms to the end of the left arm, and when in the vertical plane are turned through a right angle compared with the wielding arms.

The handle besides forming a contrivance to connect the bow arms also forms a handle or grip for the left hand; and is therefore related to the grip of the handle of a club, hilt of a sword, middle part of a javelin, and all similar devices; and it fills the hollow or barrel of the hand.

The handle is held by clasps formed by the left hand. These clasps are human, and therefore little can be seen of their construction or methods of working by direct observations, for human devices are extremely complex; and besides

forming clasps the left hand also forms a barrel, rifling devices, elevating and depressing mechanisms by means of which the angle of elevation or depression of the arrow can be changed, chequering, and probably a host of offensive devices not yet known to makers of weapons. To realize the existence of some of these devices and to study them, types of offensive machines in which the parts or devices are slightly mechanized must be studied. Some understanding of the clasps, for example, can be obtained by studying various types of crossbows, whose bows are held to the stocks by mechanical clasps or fastenings like sinews, cords, and metal grips. Each of these mechanical clasps probably illustrates some principle or principles of the human clasps. Having studied crossbow clasps some little understanding can then be obtained of the human fastenings which connect the handle of the ordinary bow to the arm and stock of the wielder's body. Until a study is made of mechanical clasps, the clasps formed by the archer's left hand and fingers can only be noticed in a general way. It can be seen that the fingers curl round the handle, that each finger forms a clasp in conjunction of course with clasps formed by the other fingers; that the clasp device where it is formed by a finger consists of three main parts, formed by the three joints of the finger. It can be conjectured that the sinews or other similar parts of the fingers help to form the clasps and give them their spring-like properties; but it cannot be known how these sinews work with those of the wielding arms and stock and legs and other parts. Many other general observations might be made, but their significances cannot be understood until mechanical clasps are studied.

The bow arms decrease in girth from the handle to the bow nocks. The human arms decrease in girth from the shoulder to the wrist, not regularly and evenly as bow arms decrease; but comparing bow arms with human arms it can be seen that the upper bow arm points upwards and the lower one downwards, and that the portions near the bow nocks correspond to the forearms and those nearer the

handle to the upper arms. This can be seen, in a general way, but there is seldom anything to reveal where the fore-arm of the bow begins and the upper arm ends, unless the bow is a composite bow when these parts are often clearly distinguishable. The arm of a composite bow when unstrung often bends sharply at about half way between the handle and bow nock. Archers call this part of the bow arm the "elbow" When a bow has a well defined elbow, it can easily be seen that the part of the bow between the elbow and the nock corresponds to the forearm, and the part between the handle and elbow corresponds to the upper arm. Bow arms are much more regular and mathematical in shape than human arms, as is usually and probably always the case with copies of human contrivances, for it is not possible to imitate the complex human contrivance with any degree of fidelity, and so a mechanical contrivance of some simple shape must suffice. Also, it is possible to make bow arms of a regular and simple shape because no attempt is made to copy more than a very few of the main features of the wielding arm.

The commonest type of bow consists of a single piece of elastic wood. Such a bow is called a self bow. A well known example of the self bow is the long bow, made from a single piece of yew. Many types of self bows are made from bamboo canes.

There is a great deal of difference between the structure and materials of wood and the structure and materials of the arm; and wooden bow arms can therefore correspond only distantly to human arms. But, on the other hand, there are many similarities between the structure and materials of wood and those of the human arm; and the branch of a tree, which is really a limb or an arm of the tree, is constructed on somewhat the same principles as the limb or arm of an animal or man. Therefore although a wooden bow cannot reproduce many of the characteristics of the wielding arm, the experience of makers of weapons has shown that it can reproduce some of them fairly effectively, and for ages the wooden self bow has served as a convenient and

easily obtained means of externalizing the wielding arm.

The relationships between plant life and animal life are little understood. It can be observed, however, that in a piece of wood, say the branch of a tree, the elasticity is obtained from all its parts; but the elasticity of the human arm comes only from certain components like muscles, sinews and tendons. In this respect correspondence between bow arms and the wielding arms is poor. But by means of the bow arms and bow strings together the elastic properties of the wielding arms are copied effectively enough for the mechanical and human arms to work together to throw an arrow or pellet.

A remote but easily recognizable correspondence is evident between the outer structures and materials of the bow arms and wielding arms when the bark of a self bow remains on the bow; for the bark, which is the skin of the wood covers the bow arms in much the same way as the skin covers the wielding arms. Self bows are often wrapped with various materials, to strengthen them against breakage or splintering; and these bows are called "wrapped bows". The bows in Western Congoland, for example, before they were ousted in favour of the gun and spear were bound with the skin of the monitor lizard.[3] Bow wrappings form an artificial skin for the bow arms; and the makers of wrapped bows when trying to prevent breakages or splinterings or the penetration of moisture also reproduced, perhaps unconsciously, a prominent feature of the wielding arms.

A type of bow intermediate in type between the self bow and the composite bow is the sinew-backed bow, a type made by the Eskimos, some North American Indian tribes, and found also in Northern and Central Asia, and occasionally in India, China, and elsewhere. The most noticeable special feature of the sinew-backed bow is a cable or band of sinew strings laid along and fastened to the back of the bow often from one nock to the other. J. G. Wood describ-

[3] Sir Harry Johnston, G.C.M.G., K.C.B., Hon. D.Sc.,Camb., *George Grenfell and the Congo.*

ing a sinew-backed bow in his possession made by the Aht tribe of Vancouver says:—

"The bow is an admirable specimen of savage art, and must be the result of long experience . It is four feet three inches in length, and made of one piece of wood. In general shape it resembles the bow of the Andamans, though it is not of such gigantic dimensions. In the middle the wood is rounded, so as to form a handle which is nearly four inches in circumference. From the handle to the tips, the wood is gradually flattened and widened for about fourteen inches, where it is just two inches wide. From this point it gradually lessens again to the tip, which is rounded and thickened, so as to receive the notch for the string.

"Were no addition made to the bow it would still be a powerful weapon, but the maker has not been satisfied with the simple wood, and has strengthened it with a wonderfully complex arrangement of strings made of twisted sinews. In my specimen there are rather more than fifty of these strings, which are laid on the bow and interwoven with each other in a manner so strong and neat, that the most skilful sailor might be envious of such a piece of handiwork. Each of these strings is double, the two strands being about as large as thin whipcord, and when seen against the light they are quite translucent.

"They are put on in the following manner. Two deep notches, parallel to the line of the bow, are made at each tip, these notches serving two purposes—first, the reception of the bow-strings, and the next the support of the strengthening strings. Eight of the strings, measuring about eleven feet in length, have been doubled, the loop passed over the tip of the bow, and the strings led along the back over the corresponding notch at the other tip, and brought back to the middle. These strings lie parallel to each other, and form a flat belt from one end of the bow to the other. About an inch below the tip, three other sets of strings are fastened in a somewhat similar manner so that four distinct layers of strings run throughout the length of the weapon.

"Even these have not sufficed the maker, who has added

six more layers starting from the widest and flattest part of the bow, so that nearly three feet of the centre of the weapon are strengthened by no less than twelve layers of sinew strings . . . The strings are laid on the bow with extreme ingenuity, so that whether the weapon be bent or unstrung, they all keep their places. So firmly are they lashed to the bow, that even when it is unstrung they are all as tight as harp-strings.

"The string of the bow is made of the same material as those which strengthen the back, and in consequence of the very great strength of the material, it is much thinner than the string of an ordinary archer's bow. It is made of two strands, each strand being about as large as the back strings . . ."

The flexible and rigid parts of the sinew-backed bow lie alongside each other, in somewhat the same way as the flexible and rigid parts of the arm lie alongside each other; and several of the components of the bow somewhat resemble components of the human arm in shape and materials. Thus the strings along the back of the bow and the clasps which hold them to the bow are made from sinews taken from an animal, and in materials and construction of materials resemble human sinews. When the bow stave is made from bone, as is often the case, and horn, whalebone, or strips of hide, are placed between the sinew backing and the stave, resemblance of materials is even closer. But in certain ways the anatomy of the sinew-backed bow differs markedly from that of the human arm. Thus, for example, the sinews or soft and flexible parts of the bow are on the back or convex side, but the sinews, tendons, muscles, and other soft and flexible components of the human arm are mainly on the inside or concave side of the arm. But the differences in positions can perhaps be accounted for as a result of transference of parts, the sinews of the bow being transferred from the concave to the convex side of the stave (Rule 8). The sinews of the bow, however, are not all transferred to the back, for the bow strings, which are also made from sinews, are still on the concave side of the bow. The

sinew-backed bow, unlike the composite bow and some self bows, is not wrapped, and thus does not reproduce the skin of the arm.

Another type of bow intermediate in type between the self bow and the composite bow has the sinews moulded on to the wood of the bow. According to Balfour, " The peculiarity of this type, which is distributed over a fairly wide area of North-West America, is that, instead of the sinew backing being composed of plaited sinew cords, kept close to the bow by means of cross binding of similar material, it consists of a *mass* of sinews taken from the back or neck of some animal, not divided up into strands or cords, but moistened and then moulded in layers directly on to the surface of the bow, so that the whole forms a very compact weapon, the composite structure being far less obvious than in Esquimaux bows with 'free' backing." He also quotes Sir E. Belcher as saying, "the wet layers of sinews are applied, so as to entirely encase the wood . . . The horns (ends) of the bow are also moulded entirely from it, and, when dry, it presents the translucent features of horn. The face of the bow is then polished off to show the wood. These bows are preserved with the utmost care in fur cases to prevent moisture reaching them, by which their strength would be materially diminished." The sinew moulding is sometimes reddened or blackened and sometimes left in its natural colour.[4]

The bow backed with moulded sinew clearly represents an attempt to reproduce certain features of the wielding arm more closely than is possible by means of a bow backed with "free" sinews; but correspondence is more remote in certain respects, for the sinews of the moulded bow cannot move relatively to the wood as can those of the free backed bow. The sinews of the wielding arm, of course, do move relatively to the bones. By colouring the moulding attempts seem to be made to reproduce the colouring of the flesh and other components of the wielding arm.

[4] H. Balfour, M.A., F.Z.S., The Structure and Affinities of the Composite Bow, *Journal of the Anthropological Institute*, Vol. XIX, 1890.

The composite bow reproduces several features of the wielding arm; but its parts have no relative movements, and thus although a composite bow reproduces more clearly certain features of the wielding arm than either the sinew-backed bow or the bow backed with moulded sinew, it reproduces others less clearly.

There are many varieties of composite bows. The composite bow, as the name given to it indicates, is composed of many materials, many of which, like bone, sinew, and skin, are also components of the human arms. A section taken through the middle of the arm of one bow, by H. Balfour, showed the core was formed by a flat piece of cane. To this, on the belly, or inside of the bow when strung, was glued a thick piece of horn. On the back was moulded first a layer of sinews, and over this a layer of mixed sinews and glue. At the sides were two thin strips of horn covering the ends of the several components. Over the layer of mixed sinews and glue was a fine, delicate layer of the inner bark of birch, which was covered by a layer of coarser bark. The various components varied in shape and thickness at different parts of the bow, and sometimes, as at the grip, other components were included.

The composite bow is nearly always covered with skin, bark, or other skin-like material, or lacquered or painted, so that it is sometimes mistaken for a self-bow. The purpose of the outer skin-like covering may be to protect the component parts from damage and especially from moisture; but this external covering reproduces fairly faithfully the skin of the wielding arm, of which it is a crude artificial copy and extension. The elaborate structure of the Persian composite bow is usually concealed by a coat of lacquer which is often highly decorated with designs, in much the same way as the human arm is often tattooed; and the adornments of the bow arm may be said to correspond to the tattooing adornments of the human arm.

The sinew-backed bow and the composite bow are curved after being strung in the opposite way to that in which they are curved before being strung. Before being strung the

belly lies on the convex side, but after being strung lies on the concave side, the bow being, as it were, turned inside out on being strung. In some specimens of composite bows the points of the bow nocks may touch or even cross before being strung. When the human arms are brought to the front of the body, so that the fingers meet, the outline of the composite bow can be seen; the human elbows corresponding to the "elbows" of the bow, or places where the bow arms make a sharp bend. The sinews and other cord-like components of the human arm are on the inside or concave side. Before the bow is strung, its sinews are similarly on the concave side. When it is strung, however, they are on the convex side, their positions compared with their human counterparts being reversed; and it can be seen then how sometimes parts of weapons can be reversed in positions relative to their human counterparts, or relative to corresponding parts in other weapons.

The bow string is really two strings placed end to end, as is indicated when the middle portion is wrapped with binding to prevent abrasion by the butt of the arrow. Also since there are two bow arms, it is likely that there are also two strings.

The bow strings correspond to string-like components of the wielding arms; but do not lie quite alongside the rigid mechanical components, formed by the bow arms, as presumably, the string-like human components lie alongside the bones. Before the bow is strung, and in some types of bows before the bow is drawn, however, the strings may lie nearly alongside the bow arms. Since the upper bow arm corresponds to the wielder's right arm, the upper bow string evidently corresponds to the string-like components of the wielder's right arm, and the lower one to the string-like components of the wielder's left arm. The bow strings are fastened to the bow arms probably in a manner which corresponds to the manner in which the strings of the arm are fastened to the rigid parts of the arms; but correspondence between the ways in which bow strings are fastened to bow arms and the ways in which human tendons, muscles, sinews,

and other components which form the wielding cords of the arm are fastened to the bones is extremely remote. Some correspondence however must exist, or the bow strings and bow arms could not work in harmony with the human strings and arms.

The bow strings and nocks besides forming attachments to connect the flexible and rigid components of the bow, form devices to correspond to those formed by the fingers and strings of slings to connect the sling to the body. Often, in order that the bow can be unstrung when not in use, only one string end is fastened to a bow nock. The other is lightly attached, sometimes by a half-hitch or other similar type of knot, which can be easily and quickly made and undone. Clearly the devices formed by the bow nock and the lightly attached string end correspond to those formed by the fore-finger and string end when a simple sling is held, and those formed by the other bow nock and the permanently fastened string end correspond to those formed by the other fingers and other string end when the sling is held.

The string ends of a sling make grooves in the skin and flesh of the fingers in which to lie. Mechanical forms of these grooves can be seen in the grooves often cut in bow nocks to help to hold the strings: and it is clear the human grooves automatically made by the ends of slings and those made in bow nocks have much the same purpose. The human grooves, however, vary in forms to adjust themselves to the tensions of the strings at any moment. Thus, for example, the grooves become deeper and better defined as the sling is being whirled and the tension of the strings increased The tensions exerted by bow nocks on string ends vary as the arrow is being drawn and set free; but the shapes of the mechanical grooves in the nocks cannot vary as the shapes of the human grooves in the hands of the slinger can do.

The string ends of bow strings form devices complementary to those formed in the bow nocks, for they fit into the bow nocks. The maker, of course, tries to make the shapes of the bow nock grooves complementary to those the string ends will have when fitted to the bow nocks.

A bow nock holds the strings much as the hand holds the ends of a sling; and is a modified reproduction of the device or contrivance formed when a hand holds string ends, say of a sling. But the bow nocks are not near the hands of the archer, because they are in transferred positions. The lower bow nock is transferred simply from the left hand which holds the handle. But it is not easy to see how the upper bow nock has been transferred. But it is at the end of the upper string opposite the right hand, and perhaps has been transferred along it.

The bow strings are in the same plane as the bow arms. This plane is approximately in the plane of the wielding arms when the bow is held horizontally, but is turned through a right angle when it is held vertically.

Chapter 29

THE BARREL AND BREECH

THE barrel of the ordinary bow and arrow machine is human. It is in two main parts. One part is formed by the left hand fingers; the other by the right hand fingers.

The foreshaft of the arrow as it rests on the left hand makes a slight indentation or groove in which to lie. This indentation or groove forms the fore part of the barrel. The arrow is shot along or just over the slight groove or barrel, which has the shape of part of a cylinder, since the foreshaft of the arrow is approximately cylindrical and impresses its shape on the skin and flesh of the fingers. The depth and shape of the fore part of the barrel depend mainly on the weight and shape of the foreshaft, and a heavy arrow will make a deeper groove or barrel than a lighter arrow.

FIG. 35. ARCHER
Viollet-le-duc

A complementary part of the barrel is formed by the right hand fingers, or fingers and thumb, as they hold the butt of the arrow. Because of their pressure, the shape of the butt is impressed on the skin and flesh where the fingers are in contact with it, and grooves are formed and parts of a cylinder are reproduced.

The barrel is not continuously formed, and the two parts of the barrel are separated by the distance between the hands; but since the surface of the arrow is continuous from the

left hand to the right, parts of the same cylinder are formed by the left hand and right hand fingers; and the axis of the arrow is also the axis of the barrel.

The distance between the hands varies at different times. Before the arrow is drawn, the hands are nearly together, and the human parts of the barrel are near each other. As the arrow is being drawn, it is drawn along the human groove in the left hand fingers until the two parts of the barrel become fully separated.

The fore part of the barrel is formed on the under side of the foreshaft, but the back part usually at the sides of the butt. The way the butt is contained in the barrel, however, depends on the style of shooting; and it may be contained partly by the thumb and forefinger, by the forefinger and middle finger, or in other ways. The way the fore part of the barrel is formed depends also on the style of shooting, and it may be formed by the thumb or forefinger or by both together or by the fork of the thumb or by other parts of the fingers.

It may seem a trivial circumstance that the arrow makes a slight indentation as it rests on the left hand fingers and that the shape of the butt is impressed at the same time on the right hand fingers. But the importance of noticing and studying these human grooves can be understood when it is realized that the barrel of the rifle and shot gun and other fire arms has been directly developed from the human barrel of the archer, and that intermediate forms between the barrels of the bow and arrow machine and gun machine can easily be discovered.

The study of apparently trivial circumstances forms the basis of all sciences, and knowledge can increase only when we are willing to notice and try to see the significances of circumstances which seem almost unworthy of notice. Thus, the science of electricity came into being because it was noticed that amber and certain other substances when rubbed can attract bits of other substances, a fact that seemed so trivial and useless to study that for centuries those who did study this and similar facts were ridiculed, those

ridiculing them asking what good could come of wasting time in such childish studies. Today, civilized man is almost dependent on the results of the discoveries made by those ridiculed pioneers. James Watt wondered why the lid of a kettle rose when the water boiled, and studied this apparently trivial occurrence, and as a result the powers of steam were harnessed to man's use. We venture to predict that, in a time not very distant, as a result of studying the way an arrow lies on the hand, the way a club or spear is held, and other similar apparently trivial matters, the theories and practices of medicine, surgery, anatomy, biology, physiology, psychology, and other similar branches of science, will be revolutionized and great new powers obtained by man, and that the effects of the study on philosophy and theology will be profound.

The left hand and fingers besides forming a barrel for the arrow's foreshaft to rest in form a barrel to hold and contain the handle; and the handle is held in the barrel or hollow of the hand in much the same way as a club handle or sword hilt is held.

The bow handle is approximately cylindrical, and as the hand and fingers grasp it they automatically and necessarily take its shape, and parts of a cylinder are reproduced on the insides of the hand and fingers where they are in contact with it. If the handle could be removed without altering the shape of the hand, it would be seen that the form of a cylinder had been impressed on the inside of the human barrel. This cylinder would not be quite smooth and even, because the creases on the fingers and palm and the grooves between the fingers would prevent the skin taking an exact cylindrical shape. The barrel would be seen to be rifled, the rifling being formed, as has been explained, by the three grooves between the fingers and the three sets of creases at the insides of the finger joints. The part of the barrel which encloses the handle is human and little can be learnt about it by direct observation.

Two barrels are therefore formed by the archer's left hand, one being formed to hold and enclose the bow handle and

the other to hold and support the foreshaft of the arrow. These two barrels, it will be noticed, are always at right angles to each other. Thus, for example, when the arrow is pointed horizontally, the axis of the bow handle is vertical; and as elevation is increased the directions of the axes of the arrow and bow handle are changed by the same amounts, so that they always remain at right angles. Hence the directions of the axes of the human barrel for the bow handle and of the human barrel for the foreshaft must also always be at right angles to each other, since the axes of the barrels coincide with the axes of the bow handle and arrow's foreshaft. The two barrels are therefore closely related in directions, for one is always at right angles to the other. The barrel for the foreshaft of the arrow is indeed an extension of the main barrel or hollow of the left hand which encloses the bow handle, turned through a right angle.

It will be remembered that the billiard player forms two *barrels with his left hand. One barrel is formed by the* hollow of the hand as it rests on the table, but this barrel does not enclose the cue. The other barrel, which is at right angles to the hollow or main barrel of the hand, holds and supports the fore part of the cue. In the bow and arrow machine, both components of the fore part of the barrel hold and support objects, for the hollow of the hand holds the bow handle, and the extension at right angles to it holds and supports the foreshaft of the arrow.

The way one part of the offensive machine can be given an extension, and that part then be turned through a right angle is thus well illustrated by the barrel devices formed by the archer's left hand; for the hollow of the left hand is given a human extension by means of the slight indentation made by the foreshaft of the arrow in the fingers, and this human extension is exactly at right angles to the main part of the barrel from which it has been derived. In the bow and arrow machine, it can be said the barrel of the left hand is split up into two components, one of which is turned through a right angle compared with the other.

Both components of the barrel of the left hand of the

archer may be human; but ways in which the components have gradually become mechanized so that eventually the gun barrel has been developed can be seen by studying various types of the bow and arrow machine.

If the foreshaft rests against the handle, the fore part of the barrel is partly mechanized, for the foreshaft is then supported and guided not only by the left hand fingers but also by the wood of the handle. When an archer stands to shoot and holds the bow horizontally and the foreshaft rests on the handle and is shot along or just over it, the barrel is also slightly mechanized, the barrel for the foreshaft being formed then by the wood of the handle and by the fingers placed against the foreshaft to hold and guide it.

The barrel is partly human and partly artificial when the archer lies down to shoot and places his feet on the handle and draws the strings with both hands. The arrow rests on the handle, and the barrel for the foreshaft is then formed by the wood of the handle, and by the insides of the feet placed against the foreshaft to hold and guide it. A complementary and human part of the barrel is formed, to hold and guide the butt, by the fingers of both hands as they hold the strings and press against the butt.

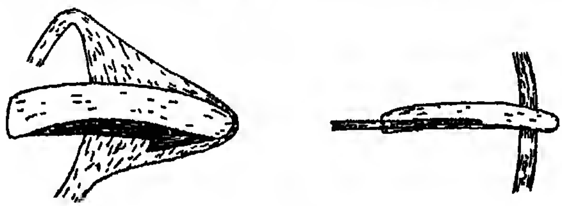
The Temiang bow of Sumatra is held horizontally, and the arrow is shot through a hole in its handle.[1] The Temiang archer's barrel is therefore more mechanized than the ordinary archer's barrel, for the wood of the barrel surrounds the missile. The barrel is not fully mechanized, of course, because the left hand must hold the handle and form a barrel for the handle, that is, must form the vertical component of the fore part of the barrel, and the barrel for the handle helps to guide and control the missile. A complementary part of the barrel is also formed at the butt, but this part is not mechanized, and is formed only by the archer's right hand fingers.

The part of the barrel which encloses the handle is partly mechanized when the handle is wrapped with binding made

[1] E. S. Morse, *Bulletin of the Essex (U.S.A.) Institute*, Vol. XVII, 1885.

of skin or other material; because the binding forms a lining for the barrel of the left hand and takes the form of a cylinder to enclose and hold the handle. The vertical component of the fore part of the barrel is then partly human and partly artificial.

The slight horizontal indentation or groove made by the foreshaft of the arrow resting on the left hand fingers is found as a mechanical contrivance when the Mongolian or Turkish bow and arrow is being wielded. The Turkish arrow, of the light type used for flight shooting, does not rest directly on the hand which holds the bow, but rests in a shallow horn groove,[2] about six inches long, secured to the



(i) (ii)

FIG. 36.
(i) Horn groove and strap, *Pitt Rivers Museum*
(ii) Arrow in horn groove

hand by a cord or strap, *Figure 36* (*i*). It serves much the same purpose for the Turkish archer as the human groove serves for the ordinary archer. When the bow is being drawn the arrow is drawn back along the groove in a similar manner to that in which the arrow is drawn back along the human groove. The groove in the flesh is replaced by the mechanical contrivance of the horn groove, which acts as a rudimentary mechanical barrel for the foreshaft of the arrow. The direction of the horn groove is the same as that of the human groove and lies similarly in the direction of the arrow.

Certain advantages are gained by replacing the flesh groove by a mechanical device. The mechanical device can

[2] G. A. Hansard, *The Book of Archery;*
E. S. Morse, *Bulletin of the Essex Institute,* Vol. XVII, 1885;
Sir Ralph Payne-Gallwey, Bt., *The Crossbow.*

be made deeper and wider and longer than the human one. Its surface can be polished so that there may be little friction as the arrow is drawn and shot along it. Its use prevents any danger of hurting the skin of the archer as the arrow is being drawn and shot. When a horn groove is used, the foreshaft when the arrow is drawn need not reach to the handle, and shorter and lighter arrows, suitable for flight shooting, or distance shooting, can be used; and shots of more than 800 yards can be made.[3] The range of the long bow arrow, over a flesh groove, is not more than about 300 yards.[4] These and other advantages, however, are accompanied by disadvantages, one being that the mechanical device requires to be manufactured and to be fitted to the hand and its method of use learnt. The mechanical device is therefore not so convenient as the human device.

It is important to notice that when the horn groove is used, the left hand is not entirely replaced as a guide for the arrow, nor released from its task of helping to form the barrel, for the hand must form a support for the mechanical device and control it. The horn groove and the hand together form a single contrivance to support and guide the foreshaft. This contrivance is in two main parts. A mechanical or artificial part is formed by the horn groove, and a human part is formed by the hand which holds it. The mechanical and human parts of the contrivance are complementary, for neither by itself is sufficient as a guide, and the horn groove cannot act as a rest for the arrow unless supported by the hand, and the hand cannot form a barrel for the foreshaft of a flight arrow if it is drawn back well past the handle. Also, the left hand must still form the vertical component of the fore part of the barrel, to hold the handle.

A rudimentary mechanical barrel is sometimes formed by a grooved board held by the left hand with the bow held horizontally. This type of barrel is used by a Siamese archer when shooting poisoned arrows.[5] The grooved board

[3] Sir Ralph Payne-Gallwey, Bt., *The Crossbow.*
[4] *Horniman Museum Handbook,* War and the Chase.
[5] E. S. Morse, *Bulletin of the Essex Institute,* Vol. XVII, 1885.

in which the arrow runs would seem to be somewhat similar in principle to the Turkish archer's horn groove.

An elementary type of mechanical barrel, which partly replaced the flesh groove as a barrel was formed by the metal groove of an ancient Egyptian archer. The Egyptian archer sometimes wore a metal groove on his foreknuckle, in which the arrow rested when drawn and ran while being drawn and shot.[6] The metal groove was somewhat similar to the horn groove of the Turkish archer, and, like the horn groove, was a crude mechanical reproduction and extension of the flesh groove.

When the Mongolian, Siamese, and Egyptian sipers, or grooves, are used the barrel is formed chiefly on the under side of the arrow, but also to some degree at the sides. The Korean archer however uses a very long siper which almost surrounds the arrow, only its top ridge showing. The Korean siper is 29 inches long, and consists of a light bamboo cane of just sufficient diameter to enclose the arrow without gripping it.[7] It has a piece of string attached to its end with a loop which is held by a finger of the right hand. The arrow is laid in the siper; and the siper and arrow are shot together, but since the siper is fastened to the finger of the right hand of the archer it does not go far, and the arrow soon leaves the siper and shoots out from the barrel thus formed by the siper, the siper of course remaining near the bow and attached to the finger of the archer.

The mechanical part of the barrel of the Korean archer who uses a siper is therefore almost fully formed, for it nearly surrounds the arrow. Since the siper and arrow move forward together for a short distance, the barrel is shot with the missile. But the feature of a missile moving through a barrel is reproduced as soon as the string attached to the right hand becomes taut. A siper of this type to form a barrel was used also by the Arabs who called it a Majra.

The length of the barrel formed in the skin and flesh of the

[6] Sir J. Gardner Wilkinson, D.C.L., F.R.S., F.R.G.S., *The Manners and Customs of the Ancient Egyptians.*
[7] *Manchester University Museum Guide Book.*

archer's left hand for the foreshaft to rest in depends partly on the manner of holding the bow and partly on the weight of the arrow. A heavy arrow will make a longer barrel for its foreshaft than a lighter one. If the arrow rests on the forefinger and thumb, the barrel will not be continuously formed; and the front part, formed by the forefinger will be separated by a small distance from the part formed by the thumb. The length of the foreshaft's barrel measured from the front part of the forefinger to the back part of the thumb, may be a few inches, but will not be as long as the wooden or metal or horn groove.

Some foreshaft barrels are shorter than the barrel formed by the flesh groove, even when the flesh groove is formed only by the forefinger or by the thumb alone. The mechanical part of the barrel for the foreshaft formed by the handle when an archer shoots lying down is shorter than the flesh groove; because, if the handle is of circular section, the lower edge of the cylinder formed by the foreshaft rests on the circumference of the handle and is tangential to it, and touches it merely at a point. The length of the barrel of the Temiang bow depends on the shape of the hole. It is longer than that formed by the handle of a bow when the archer shoots lying down, but may be shorter than the part of a barrel formed by a flesh groove.

The breech chamber of the ordinary bow and arrow machine is formed by the right palm, which makes a pouch as a continuation of the parts of the barrel at the butt. The breech is not mechanized. The chamber cone, or part which connects the barrel and breech, is formed by the devices which connect the fingers and palm.

The inner surface of the breech is formed by the palm. The breech is extremely complex and possesses many parts and devices. A few can be observed, in a general way. Prominent creases can be seen on the palm as the hand closes to form the pouch. The interior of the breech is covered with a multitude of fine lines. The material of the interior is of skin. The exterior of the breech has many of the features of the back part of a fist. And so on.

The relationships between the barrel and breech of the bow and arrow machine and the barrel and breech of the club or thrusting spear machine can be illustrated in a simple way by continuing the experiment described in the chapter on the spear. It will be remembered that the two pencils placed in the fists revealed that the bare fists have barrels and showed the directions of their axes. When the pencils were brought into the same straight line and were replaced by a cane, the ways in which the two parts of the barrel for the fists are related to the two parts of the barrel for a thrusting spear were revealed. To obtain the barrel of the bow and arrow machine, now hold the cane firmly with the left fist, and slide the right hand back until the butt of the cane is clear of the palm and is held only between the forefinger and thumb. The butt of the cane will then be held by the right hand as it is held sometimes by an archer. The fore part of the cane must now be withdrawn from the barrel of the left fist which must be turned through a right angle and be brought back to the position it had when the attitude of the wielder of the fists was first adopted. The left fist is then placed as if holding the handle of a bow. The fore part of the cane can then be rested on top of the fist; and the attitude of the archer will be fully obtained. The back part of the archer's barrel formed by the thumb and forefinger, and the breech formed by the palm can now easily be seen; and it can be seen also that the fore part of the barrel has a vertical component formed by the hollow of the left fist which encloses the handle of the bow, and a horizontal component supplied by the groove made by the foreshaft as it rests on the top of the fist.

If the cane is returned to its original position in the hands, it can be seen how the back part of the barrel for a spear shaft is now formed nearer the middle of the shaft and lies on or partly around it. A breech as well as a barrel, it is clear, is therefore formed by the hand as it grasps a club, sword, spear, or similar type of weapon.

The breech of the pellet bow machine is formed by the leather pouch and the pouch of the right hand. The

mechanical part of the breech goes forward with the missile and releases it when the strings come into a straight line; but the human part does not go forward. The barrel is formed by the sides of the leather pouch and the right hand fingers pressing on the sides, much as in the simple sling machine. A fore part of the barrel is formed by the left hand. The left hand forms a barrel for the handle, but the barrel has no horizontal component, for no horizontal groove is made in the fingers as is made by the foreshaft of an arrow. The pellet, however, is shot just over the fingers, as an archer's arrow is shot over the fingers. When the strings are released. the mechanical parts of the breech and back part of the barrel go forward with the missile, and release it when the strings come into a straight line. The missile is therefore released from the mechanical part of the breech at the end of the throwing movements; but from the human part at the beginning of the throwing movements. The arrow leaves its human breech and back part of the barrel when the strings are set free, but neither the breech nor back part of the barrel goes forward with the missile. Separation of breech from butt of the arrow therefore occurs immediately on release of the strings; but separation of the mechanical part of the breech of the pellet bow and the pellet occurs only after the throwing movements have been completed, i.e., after the strings have come into a straight line. The release actions of the mechanical parts of the breech and barrel of the pellet bow from its missile have therefore been transferred from the beginning to the end of the throwing movements (Rule 9).

The ordinary bow and arrow machine has a simple type of extensible barrel. Just before the arrow is drawn, the back part of the barrel which is formed by the flesh grooves in the right hand fingers is close to the fore part which is formed by the flesh groove in the left hand fingers; and the length of the barrel, measured from the front of the groove in the left hand fingers to the place where the right hand fingers leave the butt, is at a minimum. As the arrow is drawn, the two parts of the barrel separate, and the distance between them is at a maximum when the arrow is fully drawn. The length of

the barrel is then about equal to the draw of the bow. The distance between the hands does not change as the arrow goes forward, and the length of the barrel therefore does not vary during the forward movement of the arrow.

When the archer lies down to shoot and draws the strings with both hands and pushes with his feet against the bow handle, the length of the barrel at any moment is the distance between his hands which form the back part of the barrel and his feet which form the front part. This is at a minimum before he begins to draw the strings, and at a maximum when they are fully drawn.

The Mongolian horn groove projects a small distance beyond the bow handle, and the length of the barrel is the distance between the front of the horn groove and the right hand fingers. The horn groove gives the barrel a small mechanical extension in length. As in the ordinary bow machine, the length of the barrel varies, and is at a minimum just before drawing the strings, and at a maximum when they are fully drawn. The Mongolian bow and arrow machine therefore also has an extensible barrel. The bow and arrow machine may be said to have a telescopic type of barrel, for the barrel increases in length as the distance between the hands is increased, in much the same way as a telescope increases in length as the distance between the hands is increased.

The barrel of the pellet bow machine is extensible. Its fore part is formed by the left fist placed round the handle; but as has been said, unlike the ordinary bow and arrow machine the pellet bow machine has no horizontal component of the fore part of the barrel, for no groove is made in the fingers for the pellet to move along or over. The back part of the barrel is formed, it has been explained, when the strings are being drawn partly by the sides of the pouch and partly by the right hand fingers pressing on the sides of the pouch. Just before the strings are drawn, the fore part and the back part of the barrel are close together. As they are being drawn the back part separates from the fore part until the distance between the parts is at a maximum when the

strings are fully drawn. On release, the mechanical parts of the back part of the barrel, that is the sides of the pouch, move forwards but their human counterparts do not move forwards. Therefore during the forward movement of the pellet, the distance between the right hand and left hand fingers does not change, but the distance between the sides of the pouch and the left hand fingers decreases from a maximum to a minimum.

CHAPTER 30

THE ARROW AND QUIVER

THE chief parts of an arrow are the head, the barb, the foreshaft, the shaft, the nock, and the feathers, *Figure 37*. These parts cannot always be distinguished, and some of them are not always present. An arrow may not have feathers. Its head may not be barbed. The nock may not be well formed. The foreshaft and shaft may be in one piece. And so on.

The arrow shown in *Figure 35* lies alongside the archer's left arm, with its fore part lying alongside the forearm and

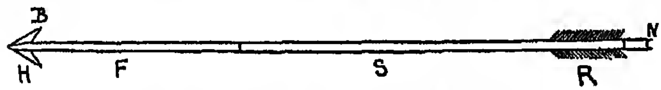


FIG. 37. PARTS OF AN ARROW
B, barb; F, foreshaft; H, head; N, nock; R, feathers; S, shaft.

its rear part alongside the upper arm. Its head and barb lie fairly close to the hand which holds the handle, the feathers and nock to the right hand. Therefore it seems the foreshaft is related to the left forearm, the shaft to the upper left arm, the head and barb to certain devices of the left hand, and the feathers and nock to certain devices of the right hand.

The arrow, as a counterpart of the left arm, forms part of the aiming machinery, for the left arm and arrow are elevated or depressed or moved round the body together as the aim is changed. The aiming machinery is only slightly mechanized by means of the arrow. Most of the machinery is human, and little can be learnt about it by direct observation. But it can be seen that the arrow and left arm and right forearm and upper arm lie as nearly as possible in a plane which is elevated or depressed as the archer wishes to shoot higher or lower, the right elbow being lowered or raised as the left fist is raised or lowered. This plane is at right angles to the

stock of the body and as the elevation is increased or decreased the archer leans backwards or forwards correspondingly to keep the plane of the arms and arrow at right angles to the stock. Human parts of the aiming machinery, it is fairly evident, are formed by both arms and by the stock.

The left arm forms also a rod or pole device to keep the bow handle away from the body; but this device is not mechanized, for the arrow does not help to keep the bow handle away from the body. It probably forms other devices, but they are not mechanized and therefore are difficult to discover.

The arrow also serves as a mechanical extension for the right arm. This is shown because before the bow is drawn it is in the same line as the right arm; and as the bow is drawn the right arm and arrow are drawn back together and to corresponding distances. The blow or thrust is delivered directly by the arrow, but primarily and indirectly by the right arm and fist or fingers of the archer. The human components of the hitting arm do not go forward to deliver the blow or thrust, and this action is performed only by the mechanical counterparts. The archer's right hand and arm are relieved of the need for going forward, but not of the need for being drawn back preparatory to delivering the blow or thrust, and the wielding arm and hand and its mechanical extensions must be drawn back together.

When the fist is the weapon, the right arm and fist are drawn back preparatory to delivering the blow, and of course must go forward to deliver it. When the fist is partly mechanized by means of a weapon bound to or held in the hand like a caestus or thrusting spear, human and mechanical counterparts are drawn back together preparatory to delivering the blow or thrust and go forward to deliver it. When the weapon is a missile, sometimes the right or throwing hand and arm go forward part of the way with the missile. Thus when the javelin or shot or hammer is being thrown or putted the hand holding the weapon goes forward

with the missile until the moment of release. When the bow and arrow is being used, however, as has been explained, the right hand and arm do not go forward to deliver the blow or thrust. Also, when the gun is being used, the right hand of the wielder of the weapon does not go forward to deliver the blow or thrust.

As the arrow goes forward the archer does not immediately change his position; and for a few moments after the arrow has passed the bow handle his left arm remains pointing along the trajectory towards the opponent or target, and his right arm and hand remain as if still helping the blow or thrust. This is a kind of "follow through" action, one well known to athletes and players of missile games.

Arrows vary considerably in length. Thus, for example, the Bushman's arrow, made of four separate parts, is only about eighteen inches long, but the arrow used for shooting fish in Guiana is sometimes six feet long. The long bow arrow was 27½ inches in length; and an arrow much longer than this cannot be fully drawn by the average archer. Indeed Saxon T. Pope says, "It is safe to say that the average archer cannot draw more than a 29 inch arrow. Even the historical clothyard shaft was a Flemish yard, or only 27½ inches, and was the usual length arrow . . . He simply cannot draw the string of a powerful bow past his cheek. This limit is well within 30 inches."

Variations in the lengths of arrows may be due to distortions; but some long arrows are perhaps mechanical extensions of both arms placed end to end, as the shafts of most spears and javelins are mechanical extensions of both arms. An arrow is indeed a type of spear or javelin; and many arrows seem to be diminutive forms of them. Thus, an arrow with a leaf-shaped head used by the Dôr tribe of Africa is very similar in shape to the assagai with leaf-shaped head; and another type of Dôr arrow with a complicated barbed head closely resembles the Bechuana assagai which has a head of a similar type, and it has been said this

Dôr arrow "if enlarged would serve admirably as an assagai."[1] *

After release, the right hand and fingers point in the direction the arrow has been shot; and the head or point may therefore be an extension of the hand or one or more of the fingers. An arrow with a leaf-shaped head may be a distorted mechanical reproduction of the wielding arm with outstretched hand and closed fingers. An arrow whose fore end is merely pointed is probably a mechanical extension of the arm and outstretched finger.

The barb, it has been explained, is not an offensive but a holding device; and on an arrow is similar to and is a crude mechanical reproduction of the device formed by a finger or the fingers as when placed round a string or cord to hold it. Its purpose is not to thrust at but to hold the opponent or creature when hit, as is clearly seen when a harpoon arrow with line fastened to it hits a creature and the wielder then holds it by means of the barb and line. The barb of course cannot hold the creature. It is the wielder who holds the creature, not directly but indirectly by means of the forefinger or fingers device transferred to the opposite end of the line to the wielder. The wielder is thus relieved of the need for having to be near the creature and of having to hold it directly.

The barb device can be considerably distorted. Distortion often takes the form of an increase in the number of the barbs, and many barbs can be found on the heads of some arrows and spears.

A thrust is given by a pointed arrow; a blow by a blunt headed arrow. Blunt headed arrows are occasionally used in the chase for knocking over small creatures. A blunt head gives a type of blow similar to one given by the fist; and the head is evidently a mechanical type of fist transferred from the right fist to the opposite end of the arrow's shaft. The

[1] The Rev. J. G. Wood, M.A., F.L.S., etc., *The Natural History of Man.*

* According to Sir Harry Johnston, "The lance or assagai was simply a big arrow."—*George Grenfell and the Congo.*

blunt head is sometimes as large as a fist, but often very much smaller. A small blunt head is perhaps a distorted mechanical copy of the fist, but more probably is a mechanical copy of one of the knuckles, distorted in shape so as not to lacerate or cut, but merely to give a dull blow.

When the foreshaft and shaft are made separately, the fastenings joining them correspond to those which join the wielder's forearm and upper arm. This is made evident because when the arrow is drawn the mechanical fastenings are usually close to the elbow of the left arm of the archer. The fastenings which join the head to the arrow correspond to the human fastenings which join the fist or hand to the arm.

Several devices are formed by the nock. The butt ends of some arrows are flat; but sometimes the nock is well developed and consists of two parts like fingers, which open and close to receive the strings and open to release them. Turkish horsemen use arrows with very well developed nocks, so that they can leave them on the bow strings ready for drawing at any moment. When the nock is very well developed and its fingers close round the strings, the archer's fingers are relieved of the task of directly holding the butt to the strings, and of releasing the butt from the strings; and it is evident that the nocks are mechanical devices which copy those formed by an archer's fingers to hold the butt to the strings and to release them from the strings. The mechanical devices are close to the archer's right hand fingers, and are transferred immediately from the human devices to the butt of the arrow (Rule 7).

When effecting release of a missile, as has been said, the fingers relax and straighten. A well developed nock performs the action of straightening its fingers as it disengages itself from the strings, but instead of relaxing its fingers makes them more taut, thus reversing the relaxing actions of the human fingers (Rule 11). The nocks are slightly elastic, and as the arrow goes beyond the strings, the strings force open the mechanical fingers, which straighten slightly as they open. As they open they become more taut.

The archer's right hand fingers let go of the strings at the

moment of release; but the fingers of the nock let go only after the strings have come into a straight line; and the mechanical actions are therefore transferred from the beginning to the end of the throwing movements (Rule 9).

When the nock is not well developed, the right hand fingers must hold the butt end of the arrow to the strings, but they are nearly released from this task when the nock is well developed; and it seems the human fingers are released from the task of directly forming the nock device to the degree proportionate to the degree of development of the mechanical fingers of the nock.

Many arrows are feathered. The feathering device may be made from bird's feathers, leaves, leather, or other materials; and arrows shot from crossbows or guns may have feathers made of wood or metal. There are usually three feathers, but a few types of arrows have only two feathers. Some used in Guiana, for example, have only two feathers. † The feathers help to keep the arrow true in flight, and if they are placed spirally on the shaft give the arrow a spinning motion as it flies.

The rifling on a gun serves much the same purpose as the feathering on an arrow in helping to spin the missile about its axis. The rifling device on an arrow is on the surface of the missile, but that on a gun has been transferred from the missile to the interior surface of the barrel. It was not discovered for many years that the rifling on the gun's missile could be transferred to the barrel, and one of the earliest and perhaps the earliest illustration of a cannon shows the rifling device on the missile, the missile being a type of arrow, and the rifling device closely resembles the feathering device of an arrow. The "feathers" are probably of wood or metal. Windage, or loss of gas, is prevented by padding the butt of the arrow, *Figure 62*.

The feathering of an arrow is a crude mechanical

† According to Saxon T. Pope, the popular impression that an arrow commonly has two feathers is caused through artists finding it easier to depict two feathers instead of three.—*A Study of Bows and Arrows.*

reproduction of the rifling device formed by the fingers as they hold the shaft of a weapon. This could be made fairly evident by some simple experiments. Thus, if pieces of paper were placed between the fingers as they grasp the shaft of a spear or other similar type of weapon, the pieces of paper would have some remote resemblances to the feathers of an arrow and the number of the pieces would be the same as the number of feathers usually provided for an arrow. Or, if the shaft were covered with some soft substance like gum or clay or putty, the substance would be forced up between the fingers as the hand grasped the shaft, and three prominent vanes would be formed and might remain on the shaft after the hand was removed and would have some resemblances to the feathers of an arrow.

The fingers are chequered with a multitude of lines and markings. Some of these human markings have been studied, and are often recorded by the police as "finger prints." Lines or markings are also formed on the feathers of birds, and it might be said the "finger prints" of birds are on their feathers. A line is made between each two barbs of a feather, and each line is approximately parallel to the next, the lines however not being straight but curved. The chequerings on a feather are more regular than those on the human fingers, but the chequerings on feathers can act fairly well as mechanical extensions of those of an archer's fingers.

Few of the purposes of the human chequerings of the fingers are known. One purpose is to allow the fingers to obtain a good grip of any object being held, in much the same way as the markings or treads on the rubber tyre of a vehicle, which are types of chequerings, allow it to obtain a good grip of the road. A purpose of the lines on a flight feather is to allow the feather to obtain a good grip of the air, and the chequerings are so directed as to allow the air to slip past without dragging on the feather and impeding its progress through the air.

The human chequerings on an archer's fingers are thus easily given mechanical extensions by using the chequering on a flight feather. Often the offensive machine is extended

artificially by using a corresponding part of an animal or plant. For example, the maker of a boxing glove uses the skin of an animal to give the skin of the boxer's fist an artificial extension. The animal's skin reproduces many of the characteristics of the skin of the boxer's hand without any effort, or even understanding, on the maker's part. The skin of the glove has pores, much of the flexibility of the human skin, resembles it somewhat in colour, has somewhat similar powers of conducting or retaining heat, and so on. Similarly, by the use of skin or leather for the sleeve of a caestus, many of the devices of the skin of the arm can easily be given artificial extensions. By the use of sinews for the strings of bows, many of the characteristics and properties of the sinews of the wielder's arms can be conveniently reproduced. Bow arms are frequently made from the branch of a tree, which is a limb of the tree, and the bow arms automatically therefore have certain essential characteristics and properties of the human arms.

A study of clothes would show that people very often and indeed usually give the clothing machinery of the body mechanical extensions by the simple expedient of using parts of the clothing machinery of creatures. Thus, the skin of the human body can be easily given a mechanical extension in the form of an additional thickness by the use of a skin of an animal. The hair producing machinery of the human body is nearly atrophied, but it can be given crude extensions, by covering the body with wool, hair, fur, feathers, or other products of the clothing machinery of creatures. A study of clothes cannot be made in this work, but could be made by using the methods of this work, and a new understanding both of clothes and of the clothing machinery of the body could then be obtained.

All the machines of the body can be studied easily by means of the human prototype theory, for all mechanical devices, contrivances, apparatuses, instruments, tools, machines, and objects, are merely artificial extensions of parts of machines of the body. The vision machinery of the body can be studied by examining lenses, spectacles, telescopes,

binoculars, theodolites, television apparatuses, wind screen wipers, and all other devices and instruments and machines that have been made as mechanical extensions of the vision machinery, each mechanical part and device of course being studied with reference to its human counterpart; the hearing machinery by examining ear trumpets, telephones, wireless sets, etc.; the vocal machinery by examining trumpets, clarionets, bassoons, violins, pianos, organs, etc.; the telepathic machinery by examining telegraphic, telephonic, broadcasting instruments, etc.; the locomotive machinery by examining boots, shoes, sandals, stilts, wheels, carts, bicycles, motor cars, tractors, etc.; and so on for other machines like the scent, feeling, speech, and memory machines. Of course, in each case, the instrument and the human machinery must be studied with reference to each other, otherwise little or nothing can be learnt either about the instrument or the human machinery. The reproductive machinery of the body, it will be shown later, is identical with the offensive machinery, and a study of the offensive machinery will also give knowledge of the reproductive machinery.

Different degrees of mechanization of the magazine of the bow and arrow machine can be seen in different types of offensive machines. The magazine is formed by the parts of the machines which provide for the hitting or thrusting actions to be repeated. In many types of the machine, the repeating actions are performed wholly by human actions, and the magazine is wholly human. Thus when there is no quiver or similar contrivance the magazine is human; and human actions are needed to obtain another arrow or pellet and to place it in its barrel and breech ready to be thrown.

The slinger sometimes carries spare missiles in a bag or net, which may be slung over his shoulder or carried at his side, or carries them in the folds of his dress, *Figure 31*. The container or chamber for the spare missiles, since it is formed by a bag or net or the dress, is an artificial or mechanical and not a human contrivance, and the magazine is slightly mechanized by the container.

The quiver of the archer contains the spare arrows in much

the same way as the magazine of a rifle contains spare cartridges; but the arrows must be taken from the quiver and be fitted to the strings by human actions, and the magazine is not much mechanized by means of the quiver.

The quiver, or magazine chamber, is formed by the left hand and handle of the bow when the archer holds spare arrows in his hand against the bow handle. The magazine chamber formed by the hand placed against the handle to enclose the spare arrows is slightly mechanized, because the handle forms part of the chamber. As the chamber is slightly mechanized, a few things about it can be noticed in a general way, but their significances can be understood, at this stage, only with difficulty. We can notice, for example, that the arrows lie in the chamber pointing upwards in the direction of the handle; that they lie alongside each other; that skilful manipulations of the left hand and fingers place each arrow in turn ready to be taken by the right hand for transference into the breech and barrel; that the arrow during the process of transference is turned through a right angle, from a vertical to a horizontal position; that the arrow is transferred from the left hand to the right, i.e., from one end of the wielding arms to the other; that the arrows when held against the handle are already in the vertical part of the rifled barrel, which it has been explained is formed by the left hand as it holds and encloses the handle, and that therefore they are merely transferred in succession from the vertical component to the horizontal component of the barrel; that the arrows lie alongside the bow arms, as nearly as possible, thus emphasizing the fact that they, like the bow arms, are mechanical extensions of the wielding arms; that until transferred the arrows lie alongside the mechanical bow arms instead of lying along the left wielding arm and forming an extension for the right arm. The reader will doubtless see other interesting points which have escaped the notice of the author; and will probably see that the mechanisms and actions of the mechanical parts of a rifle magazine merely copy in a crude manner some of the human mechanisms and actions of the archer.

The archer shown in *Figure 35* has placed two spare arrows under his foot so that they will be more readily available than if in the quiver. As he is carrying a quiver, it is clear the magazine chamber is only partly transferred to a place under his foot. We can notice the two arrows have been transferred into a horizontal position, and that they now point in the aiming direction. Since parts of the offensive machine can be transferred only from one end of a part of the machine to another, the figure seems designed to demonstrate that the quiver and the two arrows are at opposite ends of some part of the machine. This part may be formed by the left leg, which it will be shown later, forms the butt or part of the butt of the machine. As a result of transferring part of the magazine chamber from the quiver to a place under his foot, the repeating actions will be somewhat modified, for instead of the right hand going to the quiver it must go down to the foot; but the actions remain the same in principle.

Chapter 31

THE LOCK AND POWER

THE trigger, trigger spring, and other parts of the lock of the ordinary bow and arrow machine are human, and formed by the right hand and fingers. But the trigger of the Turkish or Mongolian bow and arrow machine is partly mechanized, and this machine therefore has a partly mechanized lock.

The strings of the ordinary bow are held in the drawn position by a catch device formed by the right hand fingers. The fingers curl partly round the strings to form the device, and the type of device depends on the style of shooting. It may be formed by the forefinger, thumb, first two fingers, first three fingers, the four fingers, or in other ways. Describing different ways of holding the strings, E. S. Morse says, "In the English method the string is drawn with the tips of the first three fingers, the arrow being lightly held between the first and second fingers, the release being effected by simply straightening the fingers and at the same time drawing the hand back from the string; in the Japanese method of release the string is drawn back by the bent thumb, the forefinger aiding in holding the thumb down on the string, the arrow being held in the crotch at the junction of the thumb and finger."[1] Strutt, quoting Ascham, says the archer "should hold the bow by the middle, with his left arm stretched out, and with the three first fingers and the thumb of the right hand upon the lower part of the arrow affixed to the string of the bow . . . the notch, or nock, of the arrow should rest between the fore-finger and the middle finger of the right hand . . . in ancient times, the right hand was brought to the right pap; but at present it is elevated to the right ear . . . The shaft of the arrow below the feathers, ought to be rested upon the knuckle of the fore-finger of the

[1] *Bulletin of The Essex Institute,* Vol. XVII, 1885.

left hand."[2] The nock of the arrow is probably a part of the catch device, since it helps to hold the strings in the drawn position; and if this is so the catch or holding device of the ordinary bow machine is not wholly human and the lock is slightly mechanized.

Release of the strings is effected by straightening and relaxing the right hand fingers, thus setting free the catch device. The lock of the bow and arrow machine is however human, or nearly human, and it is therefore difficult to know much about it except in a general way.

The lock of the Mongolian bow and arrow machine is partly mechanized by means of the sefin, *Figure 38*. The Mongolian archer often wears a sefin, or ring for the thumb, to draw, hold, and release the strings of his bow.[3] It is worn on the right thumb, and may be of agate, cornelian, green marble, ivory, horn, or iron, or other common or precious material, the material depending sometimes on the rank of the wearer. It has a wide lip behind which the bow strings can be caught and drawn. The strings are drawn directly by the sefin, but indirectly and primarily of course by the thumb; and the thumb and sefin together form a contrivance partly human and partly mechanical to draw, hold and release the strings, the sefin forming a mechanical extension of the human part of the contrivance. Release is effected by straightening and relaxing the thumb, so that the strings slip off the lip of the sefin. According to Sir Ralph Payne-Gallwey, the release given by use of a sefin is "as quick and clean as the snap of a gunlock when a trigger is pulled."

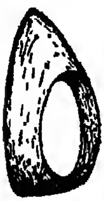


FIG. 38.
SEFIN
Pitt Rivers Museum

The sefin is a mechanical part, and by means of it the catch and release mechanisms of the lock are slightly mechanized. The trigger spring, however, is formed entirely by human parts and devices, for the sefin has no elasticity, and

[2] *Sports and Pastimes.*
[3] G. A. Hansard, *The Book of Archery;*
Sir Ralph Payne-Gallwey, Bt., *The Crossbow;*
E. S. Morse, *Essex Bulletin.*

the muscles and other components of the thumb and hand must form the powerful spring devices to keep the thumb and sefin bent until release is desired. How this spring is formed cannot be known from direct observation of the hand and thumb actions of the Mongolian archer, but some things can be known about it after a study of the springs of the locks of crossbows, shot guns, rifles, machine guns, and other weapons. But the lock springs of crossbows and guns are only partly mechanized, and the wielder's hands and fingers must form human counterparts of them, as is evident from the fact that the wielder by human actions must set the spring of the lock of a shot gun or rifle by breaking the barrels or by pulling back the bolt. Therefore, even after a study of the locks of guns, little can be learnt about the springs of locks whether human or partly mechanized.

Release of the strings does not immediately release the arrow, for the butt of the arrow does not leave the strings until they have come into a straight line at the end of the throwing movements. The pellet of the pellet bow similarly is also not released from its leather pouch when the fingers relax and straighten, but is carried forward by the pouch until the strings have come into a straight line, when the motion of the pouch is suddenly stopped, and the missile becomes separated from it. As has been stated, release of the arrow or pellet from the fingers is effected at the beginning of the forward movement, but from the strings or pouch at the end; and the release action of the arrow or pellet from the strings or pouch is transferred to the end of the movements (Rule 9). When a rifle trigger is pulled, somewhat similarly, the bullet is released from the breech, but not from the barrel, and leaves the barrel at the end and not at the beginning of the forward movement (Rule 9).

The power to drive the arrow or pellet forward is directly given by the mechanisms of the weapon. The power, before release, may be stored in the bow arms and handle, or in the bow arms alone, or in the handle alone, or even in the strings alone, the storing places depending on the type of bow. If the bow arms are made from a single piece of elastic wood,

the power is obtained from the bow arms and handle. Thus, for example, the power to drive forward the arrow of the long bow is derived from the bow arms and handle. If the bow arms and handle are made separately, and the handle is stiff and inflexible, the power is derived only from the bow arms. Modern bows are sometimes made in three pieces, and the power may be derived only or mainly from the bow arms. Occasionally bow arms are stiff and inelastic, and the handle is flexible; and the power is then derived from the handle only. Thus, for example, the power of the Athapascan bow is derived only from the handle, the bow arms being straight and stiff.[4] The power, however, may be derived only from the strings, as is the case when the toy catapult with elastic strings is used, the toy catapult being a type of pellet bow. A curious type of weapon is said by Wood to be in use in the Pelew islands in the Pacific, in which the elastic power comes from the missile. An elastic spear is bent almost double, one end being held by the pouch of a spear-thrower, the other being held in the hand. On releasing the hand the spear jumps off the spear-thrower towards the target or opponent. The weapon would not seem to be a very effective one, but Wood says the natives use it quite effectively.

The power which drives the arrow, although derived immediately and directly from the bow arms, is primarily and indirectly derived from the wielder's body. As the bow is being drawn, power from the body is progressively transferred to the bow arms until the bow is fully drawn, when it contains a power equal to the power of the archer's body.

The power of a bow is found by suspending the handle by a hook from a beam and hanging a weight from the middle of the bow string, just sufficient to draw the bow fully.

The power of an ordinary bow is usually between 30 and 80 lbs.; a bow of 30 lbs. weight being a weak bow, and one of 80 lbs. weight requiring a strong archer to draw it.

The bow arms are, or should be, of just sufficient strength to allow the full power of the muscles of the arms and chest

[4] Otis T. Mason, A.M., Ph.D., *Origins of Invention.*

of the wielder to be used. If the power of the bow is greater than that of the archer, he will not be able to draw it fully; if weaker, his full power cannot be used.

As the bow is being drawn, some of its materials become extended and others compressed. Those on the concave side, or belly, become compressed, those on the convex side, or back, become extended, and some of the materials of the sides become extended and others compressed. When the materials are extended or compressed, power can be obtained by allowing the materials to return to their original states. The power contained in the bow arms must be restrained until the moment the missile is to be released, and the archer until the moment of release must exert a power equal to the power contained in the bow arms.

When the strings are fully drawn, the bow arms are fully charged, and on releasing the strings elastic forces from the extended and compressed materials are set free to drive the missile forward.

As the power contained in the bow arms at any moment is exactly equal to the power exerted by the archer, and as they cannot be charged with more power than his body can exert, it is likely that the way power is generated and contained by the bow arms is similar to the way it is generated and contained by the wielder's body; and that the power mechanisms of the weapon are merely extensions of those of his body.

When the bow is fully drawn, the power in the bow arms must not be restrained for long, for the archer's arms and body quickly become tired. The materials of the bow similarly may become tired, and may indeed take a permanent set towards the drawn position if the power is restrained too long. Bows should be unstrung when not in use, and any power in them be set free. A strung bow already has a certain power charge, given of course by the archer as he strings the bow.

The power to deliver a blow with the fist is obtained by separating the hands and expanding the chest. Before the bow is drawn the hands are nearly together. As it is being

drawn and the bow arms are being charged, the hands become separated and the chest expands, and when the bow is fully drawn the hands are separated and the chest is expanded as much as possible.

As the bow is being drawn and charged the bow nocks approach each other; but the archer's hands separate from each other. The actions of the nocks, or mechanical counterparts of the hands, are therefore the reverse of those of their human counterparts.

When the release is effected, the muscles and other parts of the archer's body become relaxed. The bow arms and strings also become relaxed as the arrow is driven forward. The human mechanisms do not directly drive the arrow forward; and their mechanical counterparts relieve them from this task (Rule 5).

The recoil of the bow and arrow machine is slight. The shock is taken first by the bow nocks, then transferred to the left hand holding the handle, transferred then along the left arm to the body, and then to the legs, then to the soles of the feet, and is finally absorbed by the ground. The recoil machinery is very slightly mechanized perhaps, because the bow arms and handle transmit the shock to the left hand. But little can be learnt about recoil mechanisms from direct study of the bow and arrow machine.

* * * *

The bow and arrow or pellet bow machine includes the club, the spear, and the sling machines, and probably other primitive and simple offensive machines; and it can be seen there was no break in development when the bow and arrow was produced, and that it was developed by a process of absorbing or assimilating simpler types of weapons.

The pellet bow essentially is a combination of the club and the sling, and the bow and arrow a combination of the spear and sling. The main parts of the sling can be seen in the pellet bow as the pouch, missile, strings, bow nocks, and fastenings joining the pouch to the strings and strings to the bow nocks. The bow nocks, it has been explained, are mechanical reproductions of the hands. The strings of the slinger are whirled

round his hands, use being made of centrifugal force to propel the missile. The strings of the pellet bow are not whirled directly round the wielder's hands, but are directly whirled round the bow nocks, or mechanical extensions of the hands, for as the bow is being drawn, the missile and pouch move along an arc of a curve round each bow nock. This action is made possible, because although the missile moves in a straight line, the bow nocks approach each other and come more towards the wielder, and relatively to each bow nock the missile moves along the arc of a curve. The direction of motion of the missile is reversed after release of the strings, and it is then whirled with great velocity along this arc and round each bow nock, use then being made of centrifugal force. The angle through which each bow string moves is smaller than that through which the strings of a sling are usually moved, but the angle is moved through with greater velocity to compensate. A slinger, it may be said, does not always whirl his strings through a complete revolution or through several revolutions. When he wishes to throw several missiles in quick succession he may whirl them through only a small angle.

The slinger whirls his strings in a vertical plane, or in a plane which is inclined to the horizon at the angle of elevation. Similarly the archer whirls his strings in a vertical plane, or in one inclined to the horizon at the angle of elevation. The bow strings are whirled in a vertical plane when the bow is held vertically, but in a plane inclined to the horizon when the bow is held "horizontally". Clearly, the archer is a slinger.

The arrow is a diminutive form of the spear. The spear is thrust forward directly by the hands and rigid and flexible parts of the wielder's arms. The arrow is thrust forward directly by the bow nocks, bow arms, and bow strings, which are mechanical reproductions of the hands, rigid parts of the arms and flexible parts of the arms respectively. Primarily and indirectly, however, the arrow is thrust forward by the human components. The archer is thus also a spearman.

The main actions of the wielder of a club are fairly well

copied by the wielder of a pellet bow or wielder of a bow and blunt headed arrow. The essential actions of the wielder of a club when a hammer blow is being delivered are the raising of the arm and hand preparatory to delivering the blow and the lowering of the arm and hand as the blow is being delivered by the artificial part of the fist. As the bow is being drawn the upper bow nock descends and the upper bow arm comes back towards the wielder, as if a blow is being directed by the nock at the wielder. As the missile is being released these actions of the nock and bow arms are reversed The actions of the mechanical hand and arm, compared with those of the wielder of a club are thus reversed. An underhand type of blow seems to be aimed at the wielder by the lower bow nock. The actions of the bow nocks and arms result in the pellet or blunt head of the arrow going towards the opponent or target to deliver a blow, and these devices it has been explained are mechanical counterparts of the fist or of part of it. When the bow is held horizontally a swinging type of blow is delivered by the bow nocks and arm. The archer it is fairly evident is therefore also a wielder of a club. It can therefore now be seen that the pellet bow or bow and arrow machine has been developed from the club, spear, and other machines, by a continuous process of development, no essential features of earlier machines being lost but all conserved in later machines; and it is likely therefore that gun machines contain similarly all the essential features of club, spear, bow and arrow, and earlier machines. It is likely also that future weapons, for example atomic weapons, as they develop must retain or recover all essential features of earlier machines. In particular, it is likely that the wielder of an atomic weapon of the future must be a wielder of a club, spear, bow and arrow, rifle, and most other types of earlier weapons; and that a study of an atomic weapon will reveal it possesses all the parts and devices of earlier offensive machines, and no others.

It may be pointed out that, logically, the onus of proving that, say, the clubman, the archer, the rifleman, and the

wielder of an atomic weapon, use different principles is on those who think that different principles are used. According to scientific dogmas nothing should be assumed without proof. In this work, there is no assumption that later weapons embody different principles from earlier ones; and the assumption does not need to be used. The belief that any weapon or indeed any mechanical instrument has been invented can be supported by no proofs.

CHAPTER 32

THE CROSSBOW

THE crossbow differs from the bow and arrow most evidently in having a wooden stock added. As a result of partly externalizing the stock of the body, the crossbow reproduces crudely, but quite distinctly, the

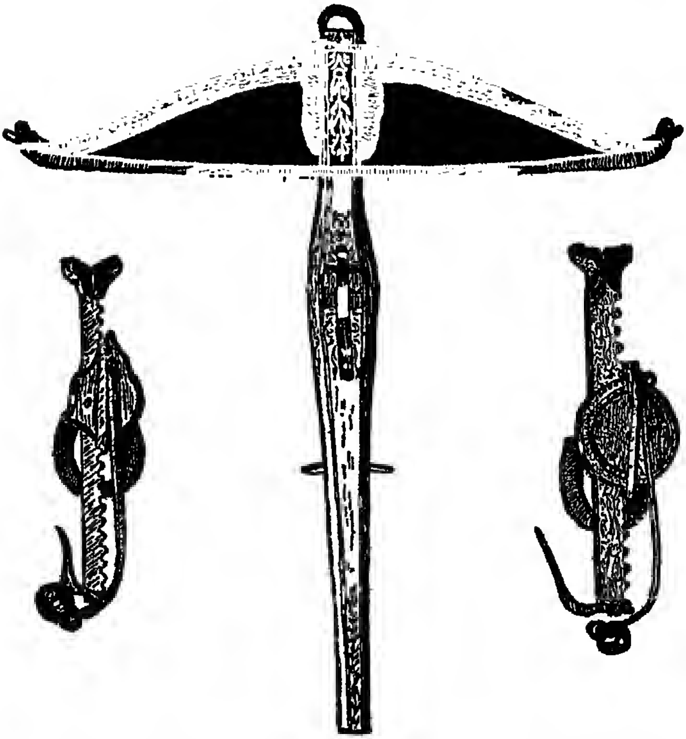


FIG. 39. SPORTING CROSSBOW AND TWO CRANEQUINS
XVIth Cent. *Victoria and Albert Museum, London*
Crown copyright (from a photograph).

outline of the human body; and if a crossbow is placed upright with its butt end on the ground, the human figure with

arms outstretched is crudely reproduced, and the human prototypes of many of its parts and devices can at once be recognized. Thus it can at once be seen that the wooden stock corresponds to the wielder's body, the bow arms correspond to the wielder's arms, and the bow strings correspond to the sinews and other cord-like components of the wielder's arms.

The bow nocks correspond to the hands, and are at the ends of the bow arms as the human hands are at the ends of the wielder's arms. The tips of the bow nocks, when they are well developed, are called by crossbow makers the "thumbs" of the weapon, and often strikingly resemble thumbs at the ends of hands, *Figures 39 and 45.*

The part of the bow between the bow arms, or handle, corresponds to the contrivance formed by the chest to connect the wielding arms; and the middle portion of the strings is an artificial extension of the cords of the chest.

The butt of the crossbow corresponds to the contrivance formed by the legs of the crossbowman.

A glance at primitive types of crossbows is sufficient to reveal the human counterparts of many of the main parts of hand weapons, notably the stock, bow arms, butt, and strings. By examining more developed types of crossbows, the human prototypes of many other parts and devices of weapons can easily be known. Thus, by placing a nineteenth century bullet-shooting crossbow* upright and comparing its

FIG. 40. BULLET-SHOOTING CROSSBOW, XIXth Cent. (Strings not shown). *Property of Mrs. Hooton, Mobberley*

parts with corresponding parts of the body, the human prototypes of the lock, magazine, bow and stock, can at once

* For a description of this crossbow, see:—
Daniel Higson, *The Bullet Crossbow;*
Sir Ralph Payne-Gallwey, Bt., *The Crossbow;* etc.

be seen. If a crossbow is not available, a shot gun or rifle will serve as well for everything except the bow arms and strings; and for most purposes will serve much better, for in certain ways the rifle or shot gun is more highly mechanized than the crossbow.

The narrower end of the butt end of the rifle or shot gun is called by gunsmiths the "toe", and the blunter end the "heel", and these parts can at once be recognized from their shapes and positions as corresponding to and being mechanical counterparts of the toe and heel of the wielder's foot or shoe. The butt end is curved underneath, somewhat after the manner of the instep; and the part between the toe and heel of the gun or crossbow is a crude mechanical copy of the wielder's instep device. When the weapon is placed upright, its toe and heel and instep are on the ground; and when a soldier, for example, stands at "attention" he places the toe of his rifle next to the toe of his boot, its heel next to the heel of his boot, and its instep almost follows the curve of the instep of his boot or foot as if to demonstrate that the butt end is a mechanical copy of the butt end formed by his foot.

There is a bend in the stock of the crossbow, rifle, or shot gun. This corresponds to and is a mechanical counterpart of the bend in the knees of the wielder or of the bend between the legs and trunk. The purpose of the bend in the stock will be studied later.

The lock of the crossbow or rifle is about mid-way between the top and bottom of the stock, and in position corresponds approximately to the position of the human reproductive organs, of which it will be presently shown it is a mechanical counterpart.

A shot gun or rifle differs most strikingly from a crossbow in outward appearance in not having bow arms and strings fastened to it. Bow arms and strings are not found on guns, one reason being that the power of the crossbow is generated by the wielder, but the power for the gun is generated in factories by others; and the bow arms and strings now form parts of the machinery for making and generating the

power of explosives, having been transferred from the weapon to the factories.

By comparing parts of a crossbow with parts of the human body, nearly all the human prototypes of the parts of the weapon can, after a little study, be known. But the crossbow, and indeed any other type of weapon, is but a crude and elementary mechanical contrivance, reproducing only very indistinctly and imperfectly some of the main features of the wielder's offensive machinery. In trying to notice correspondences between parts of a weapon and parts of the human offensive machine, we are somewhat in the position of a biologist who tries to notice correspondences between parts of an embryo and parts of a fully developed creature. Indeed we are under the disadvantage that an embryo is far less removed in development from the fully developed creature than the weapon is from the human offensive machinery. The astonishing thing is that correspondences between parts of a weapon and parts of the offensive machine are usually much more evident than between parts of an embryo and parts of a fully developed creature. It requires long training before a biologist can recognize corresponding features of an embryo and a fully developed creature, and correspondence is often difficult and may be impossible to observe. But a very little training suffices for almost anyone to be able to recognize correspondences between parts of a weapon and parts of the offensive machine. Thus, a club with a knobbed head, although almost the most primitive and least developed of weapons, can easily be recognized as corresponding to a fist at the end of an arm. A child could point out correspondences between parts of a crossbow placed upright and parts of the body.

The biologist has the advantage also of being able to see every gradation of development between the embryo and the fully developed creature. Thus, every stage in the development of the chicken from the egg to the fully developed creature can be observed. But even by following back the infinite gradations of development, it is not possible for even a trained biologist to see the feathers, beak, toes, intestines,

and other parts in the early egg stage. The student of weapons has hardly any intermediate forms between a primitive weapon and the human offensive machine, and those he has are the most primitive forms; for although the process of development of weapons has occupied makers of weapons since the beginnings of civilization, very little progress has been made in reproducing the human offensive machine, as is evident from the fact that no one hitherto, it seems, has suspected that weapons are mechanical embryos of the human offensive machine, so poorly do weapons reproduce parts of this machine.

Also the student of weapons is under the further disadvantage that weapons are not only in the most primitive stages of development towards the offensive machine, but are extremely imperfect mechanisms. There is nothing to suggest that the embryo of a creature is an imperfect mechanism. The biologist therefore has perfect intermediate forms between embryos and fully developed creatures, but the student of weapons can never study any except imperfect first forms.

It is probable that the ease with which correspondences between parts of weapons and the offensive machine can be discovered is caused by the circumstance that a weapon is an embryo of only one machine of the body. When the biologist looks at the embryo of a creature, he does not look at the embryo of one machine of the body but at the embryo of the thousand and one machines of the body inextricably mixed and combined; and he has no means of obtaining any of these machines in complete isolation from the others. But when examining weapons we see crude and elementary mechanical copies of parts of the offensive machinery isolated from all other machines. Similarly, by making a study of optical instruments, auditory instruments, locomotive contrivances, musical instruments, clothes, steam engines, internal combustion engines, electric machines, or other classes of instruments or contrivances or machines, we can see crude and elementary mechanical copies of the vision, hearing, locomotive, vocal, clothing, power, nervous, or other

machines of the body, isolated from all the other machines. In mechanical devices and machines we see the very simplest copies of parts and devices of machines of the body; and the most elementary principles of the construction and methods of working of the human machines are made evident. The student therefore who studies one machine of the body at a time, indirectly also by studying simple models of parts of that machine, has an overwhelming advantage over the student who tries to study the same machine inextricably mixed with all the other machines of the body of the existences of many of which he is not even aware.

A study of the crossbow reveals that the makers of weapons are striving, unconsciously no doubt, to reproduce the human offensive machine. It will become apparent—it has probably already become apparent to the reader—that crossbow makers like the makers of clubs, spears, bows and arrows, and other types of weapons, have not succeeded in inventing any part or device, for there is no part or device of the crossbow that cannot be shown to have its human counterpart. Reasons will also be given later to show that gun makers have probably not succeeded in inventing any part or device of a gun. It is highly improbable therefore that makers of weapons will or can make any weapon whose parts and devices are not counterparts of the offensive machine. The goal or end of man's efforts in making weapons can therefore be known. Briefly, it is to reproduce the human offensive machine. Similarly, his goal or end in making locomotive, vision, hearing, and other contrivances, is to reproduce the human locomotive, vision, hearing, and other machines. If these machines could be combined, as they are in the body, it seems the result would be man. But man already reproduces himself, as do all creatures and plants. Therefore at the end of the process it seems we shall arrive at the point that we started from, a curious sort of progress and one which reminds us that if we sail or fly westwards, one day we will arrive back at the point from which we started.

Chapter 33

THE STOCK

MECHANIZATION of the human offensive machine was carried a stage further when a wooden stock was fitted to the bow to turn it into a crossbow. The ordinary bow and arrow machine has a stock formed by the wielder's body. It is not easy to discover by direct observation how the body forms a stock for the bow and arrow machine; but some things can be known after examining various types of mechanical stocks of crossbows and guns. In the experiment with the sling, it can now be realized, a crossbow rather than a pellet bow was reproduced, the body of the wielder forming the stock in the experiment.

When an archer lies down to shoot and draws his bow by placing his feet against the bow arms, the parts of the human stock are reversed compared with their positions when the bow is held above the head for shooting. C. J. Longman, describing the method of drawing the bow sitting down, says, "The archer sits down, and placing one or both of his feet against the centre of the belly of the bow, pulls back the string with both hands. Unless he lashes the bow on to his feet, or has remarkably prehensile toes, the bow must spring forward when it is loosed, much of the additional power gained must be lost, and the direction and elevation of the arrows rendered quite uncertain. By this method, in fact, a man makes himself into a crossbow, his body and legs representing the stock on which the bow is fixed. It seems possible that this system of drawing the long-bow, which is undoubtedly very ancient, may have suggested the crossbow . . . Certainly, anyone who has practised this method of drawing the long-bow would soon find the need for a stock on which to fasten the bow, to prevent it springing away when loosed."[1]

[1] *Badminton Library,* Vol, Archery.

H. S. Cowper realized that the ordinary bow has a stock formed by the human body. "Races which draw the ordinary bow lying prone on their back, with their feet against the bow, are already acquainted with the principle of the shafted bow, since in shooting, the human body forms the shaft or stock."[2]

The wooden stock of the crossbow reproduces only a very few of the contrivances and devices formed by the stock of the wielder's body. The stock of the body forms a contrivance to hold the weapon at a certain height above the ground; a pivot for allowing the weapon to be turned horizontally through an angle; and many other contrivances which are not reproduced by the wooden stock of a crossbow; for the weapon must be held above ground by the body, it must be turned horizontally by the body, and so on. A Chinese crossbow, however, has a mechanized pivot by which it is held above ground and round which it can be turned. This crossbow will be described later.

The human stock and the wooden stock together form the complete stock of the crossbow machine; and the wooden stock is a complementary part of the human stock. When a rifleman stands to "attention", the wooden stock of the rifle is close alongside and parallel to the stock of his body; but in the aiming position becomes turned through a right angle and projects at a right angle from the human stock. At point blank range the wooden stock is horizontal, and the human stock is vertical. As elevation is increased, the inclination of the weapon to the horizontal is increased, and the inclination of the stock to the vertical is correspondingly increased, for the wielder leans backwards to keep the wooden stock at right angles, as well as he can, to the stock of his body, thus revealing the close relationships between the wooden and human parts of the stock.

The turning of the wooden stock, and incidentally of all other parts of a rifle, through a right angle is demonstrated when a soldier is being drilled and transfers the rifle from its place at his side to the aiming position, or to the position

[2] *The Art of Attack.*

known as "at the trail", which is a position in which the rifle is held by one hand hanging down, with the weapon carried horizontally. The wooden stock is changed from a vertical to a horizontal position. The butt end which was on the ground and horizontal becomes vertical. The barrel which was vertical becomes horizontal. And so on.

The butt of a weapon is the part between the lock and the ground, when the weapon is held upright with the butt end on the ground. The rifle's butt is alongside the leg of the soldier standing at attention, and must therefore correspond to and be a counterpart of the contrivance formed by his leg or legs. Like the stock, the butt is turned through a right angle as the weapon is brought to the shoulder to be aimed (Rule 10).

The butt in some machines is formed by both legs, in some others by one leg only, in others sometimes by one leg and at other times by both legs. Thus, the butt of the fist machine is human, and is formed usually by both legs, but at times may be formed only by one leg. The butt of the shot putting machine is formed at first by the right leg. As the putter moves forward, it is formed by both legs, i.e., when both feet are on the ground. As the missile leaves his hand, the butt is again formed only by the right leg, for at that moment he stands only on the right foot. The butt of the archer, crossbowman, and rifleman, is formed usually by both legs.

The stock of the rifle, shot gun, or other hand gun, when the weapon is placed upright, does not bifurcate, or become two parts, towards the ground, as the body bifurcates. But the stocks of some types of crossbows do bifurcate, so that the butt has two rudimentary types of mechanical legs. A glance at the Fan crossbow in *Figure 41* (*i*), shows its long stock split into two limbs. In the second type of Fan crossbow, *Figure 41* (*ii*), the two limbs, or legs, rejoin to form a single butt end. The first type of Fan crossbow therefore has two butt ends, but the second type only one butt end. As stated in the preceding paragraph, the wielder's body usually forms two butt ends, but if he puts most of his weight on one

leg, the butt end of the machine will be formed mainly by that leg, and if he puts all his weight on it will be formed only by that leg.

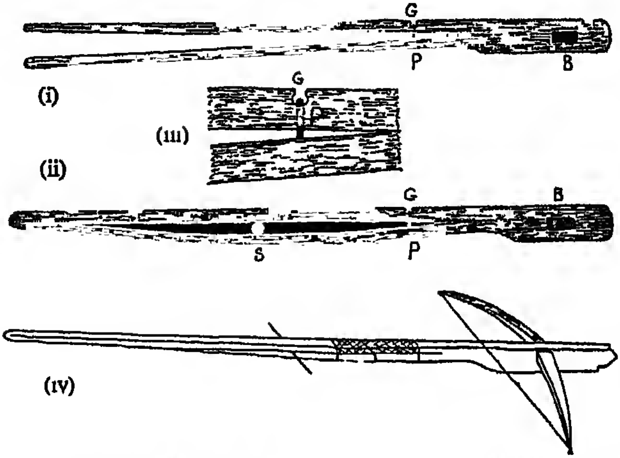


FIG 41. FAN CROSSBOWS. *Pitt Rivers Museum.*

(i) Type with split stock
(ii) Type with partly split stock, with stick keeping limbs open
(iii) Lock of Fan crossbow, showing peg for pushing out the strings
(iv) Fan crossbow, type (ii)
B, hole for bow arms; G, string groove; P, peg; S, stick.

Therefore, looking at a Fan crossbow placed upright, the outline of the human body with arms outstretched is foreshadowed; and on looking at its side, the two legs can be seen forking from about the lock and continuing to form two butt ends or rejoining to form one butt end.

Details of the construction and actions of the Fan crossbows shown in *Figure 41* are as follows:—

Figures 41 (*i*) and (*ii*) show diagrammatically the sides of two different varieties of Fan crossbows. *Figure 41* (*iii*) shows the lock, enlarged. B is the rectangular hole in the side of the stock which receives the bow arms. G is the notch or transverse groove into which the strings are drawn. In type (*i*), the split stock is held open by the crossbowman until the moment of release, when he allows it to close by its own power to drive the peg P, which is fixed in the lower

limb, up through the hole in the upper limb to push out the strings. In type (*ii*), a stick *S* is inserted in the split to keep the limbs apart. To release the arrow, the stick is withdrawn. The split then immediately closes and the peg P moves up into the groove G and pushes out the strings The arrow lies on the fore part of the stock, between G and B, sometimes in a very slight groove or barrel.

Figure 41 (*iv*) is a sketch of a Fan crossbow of the second type, with a stick inserted in the split.

The stock of the Norwegian crossbow, *Figure 42* (*v*), used for whaling in the Fiords, is constructed on much the same principles as the first type of Fan crossbow, and has somewhat similar actions, but the two limbs of the stock are joined by a hinge and not by a split, and therefore the crossbowman must directly close the limbs to drive out the strings, using the lower limb as a kind of long lever or trigger. The stock bifurcates from just above the lock, as in the Fan crossbow, to form two limbs or legs of equal lengths.

The two limbs of a crossbow's stock however are seldom of the same length. The upper limb is the portion on which the arrow is placed, the lower limb is used as a kind of long lever or trigger. Usually the lower limb is shorter than the upper one. In some types of crossbows the lower limb is represented by a long lever (see *Figures 50, 54, 60, 61*), and in others merely by a trigger (see *Figures 40, 43, 46, 49, 52, 53*). In the gun machine, the lower limb is represented merely by the trigger; but in the air gun machine and in a few types of gun machines the lower limb is still represented by a long lever under the stock which is worked to charge the gun or to open its breech.

Occasionally the lower limb of the crossbow is longer than its upper limb, as in the Chinese repeating crossbow, *Figure 47*. The upper limb is formed by the bottom of the box or magazine, and has a slight groove into which the arrows drop in succession. The lower limb is the part which extends from beyond the bow arms to the shoulder or chest crutch.

Hence in some types of crossbows the lower limb of the

stock is longer than the upper one, in others the limbs are of equal length, and in others the lower limb is represented by a long lever, which becomes the short trigger in other types. There is thus a complete series of limbs or triggers between the lower limb of the crossbow which is longer than the upper limb and the lower limb formed merely by a trigger worked by a finger. It is clear the trigger of a crossbow or gun is a modified lower limb of the stock, and therefore a dwarfed or atrophied extension of the leg of the wielder.

A Benin crossbow represented on a bronze plaque in the British Museum has its lower movable limb only about two thirds the length of the upper limb, *Figure 42* (*iv*). This lower limb somewhat resembles the long lever, or tiller, found on many mediaeval crossbows, *Figures 42* (*iii*), *50, 60, 61;* and seems to be a type of limb intermediate between the full length limb as found in the Fan and Norwegian and similar types of crossbows and the long lever of the mediaeval crossbow. According to H. Balfour, "the lever of the better-known European crossbows may itself have been suggested by and derived from the movable limb of the ruder types. The muscular action required to effect the release is in both cases the same, viz., a squeezing together of the two parts of the stock in the one case, and of the lever and stock in the other . . . "[3]

Intermediate forms can be found in plenty between crossbows like the Fan and Norwegian crossbows with two butt ends, and crossbows with one main butt end and lower limb represented merely by a short trigger. It seems that from one point of view the lower limb of the crossbow has degenerated mechanically from the full length "leg" into a mere bit of a leg formed by the short trigger. From another point of view the lower limb may be considered to have progressed mechanically from the crude lower limb of the stock into the well developed trigger of the shot gun or rifle. The principle that a weapon with a mechanical stock should have two limbs or legs is thus always obeyed, but one limb may be represented merely by a short trigger.

[3] *Journal of the African Society*, Vol. VIII, No. XXXII, July 1909.

Figure 42 shows the relationships between the lower full length limb of a crossbow and the atrophied limb formed by

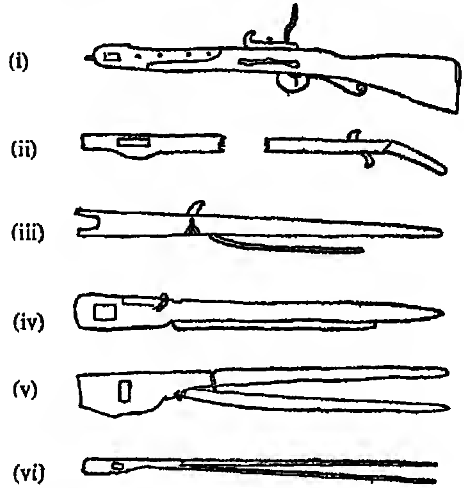


FIG. 42.
CROSSBOW LIMBS AND TRIGGERS

(i) Bullet-shooting crossbow
(ii) Malabar crossbow, *Horniman Museum*
(iii) Mediaeval crossbow, with revolving nut and long lever
(iv) Benin crossbow, *British Museum*
(v) Norwegian whaling crossbow, *H. Balfour*
(vi) Fan crossbow, with split stock

a short trigger. In *Figure 42* (*vi*), the lower limb is the same length as the upper limb, the limbs being formed merely by splitting the stock. In *Figure 42* (*v*), the lower limb is hinged by a loop at the crotch. *Figure 42* (*iv*), shows the side of the Benin crossbow with a hinged lower limb of about two-thirds the length of the upper limb. The lower limb is represented in *Figure 42* (*iii*), by the long lever or tiller found on many mediaeval crossbows. The lower limb is represented in *Figures 42* (*i*) and (*ii*), merely by a short trigger.

It is not suggested of course that the trigger of the rifle has been developed directly from the lower limb of the Fan crossbow; and the diagram merely serves to show how the trigger of a weapon like a rifle or shot gun is related to the butt contrivance formed by one of the legs of the wielder of

the weapon, and is a very distorted and diminutive mechanical copy of it.

In all varieties of crossbows the "legs" can open and close, as the legs of a wielder can open and close. Thus in the first type of Fan crossbow, the legs or limbs are open before release of the strings, and on release are closed and brought together. If the lower limb is represented in a weapon merely by a short trigger, as it is in the shot gun or rifle for example, the closing action of the limbs is represented merely by the slight approach of the trigger to the under side of the stock as it is pulled.

The limbs of the Fan crossbows are joined just above the lock by a split, both limbs being joined naturally at the fore end of the stock near the bow arms by the wood. But the limbs of the Mandingo and Benin crossbows are made separately and afterwards jointed by a loop of thong. The limbs of the Norwegian crossbow similarly are made separately, but are then jointed by a slightly more complicated hinge consisting of a tenon-and-rivet joint.[4] Since the limbs or legs of these crossbows correspond to and are crude mechanical reproductions of the wielder's legs, there must be some correspondence between the ways in which the legs of the crossbow are jointed at the crotch and the ways in which the human legs are jointed at the crotch. But of course the crossbow joints are in a most primitive stage of development and reproduce the human crotch joint only very remotely. But, if the human prototype theory is correct, there must be some similarities between the ways in which the mechanical and human legs are jointed. Probably in the different types of West African and Norwegian crossbow leg joints we see the very simplest mechanical models of the extremely complex and perfect human joint. The trigger of a hand gun, which it has been explained is a rudimentary and distorted type of one of the limbs, is jointed to the stock by more complicated mechanisms, consisting of seers, springs, and other devices of the lock; and since this type of joint is more

[4] H. Balfour, M.A., F.R.S., *Journal of the African Society*, Vol. VIII, No. XXXII, July 1909.

highly developed mechanically, probably it corresponds more closely but still very distantly to the human joint.

By studying the ways crossbow limbs are jointed to the main part of the stock we can therefore indirectly study the structure of the crotch or fork of the body, with the advantage of seeing in some crossbows the most elementary mechanical models of the human leg joint, in others slightly less elementary models, and in guns somewhat more complicated models. The great disadvantage is that no mechanical weapons have yet been made in which correspondence of mechanical and human leg joints is at all close. But doubtless, as new types of weapons are developed, correspondence will become closer.

Part of the work of the stock and butt is to take the shock of the recoil and transmit it to the ground. The wooden stock first takes the shock, transmits it to the wooden butt, which transmits it to the shoulder. From thence it is transmitted to the human stock, then to the butt formed by the legs, and then to the ground. The body forms buffers or springs to help to take the shock and to restore the weapon and body to its former position; but these devices are not mechanized and externalized, and therefore cannot easily be studied.

The nineteenth century bullet-shooting crossbow, *Figure 40,* the shot gun, the rifle, and many other types of crossbows and hand guns, have a bend in the stock near the lock where butt and stock meet. This bend corresponds to and is a crude mechanical counterpart of the bend at the knees or of the bend in the body where trunk and legs meet. When the rifle is held at attention the concavity of the bend in the wooden stock is to the front and therefore opposite to the concavity of the bend at the knees which is behind (Rule 11), but similar to the concavity of the bend of the body where trunk and legs meet which is to the front.

The amount of the bending of the wooden stock or of the body seems to be related to the violence of the recoil. The recoil of the bow and arrow machine is slight, and there is little bending of the knees or of the body. The bending of

the knees is not pronounced when a crossbow or shot gun or rifle is being wielded, but the wooden stock is bent, and the bend in the wooden stock is partly substituted for the bending of the body.

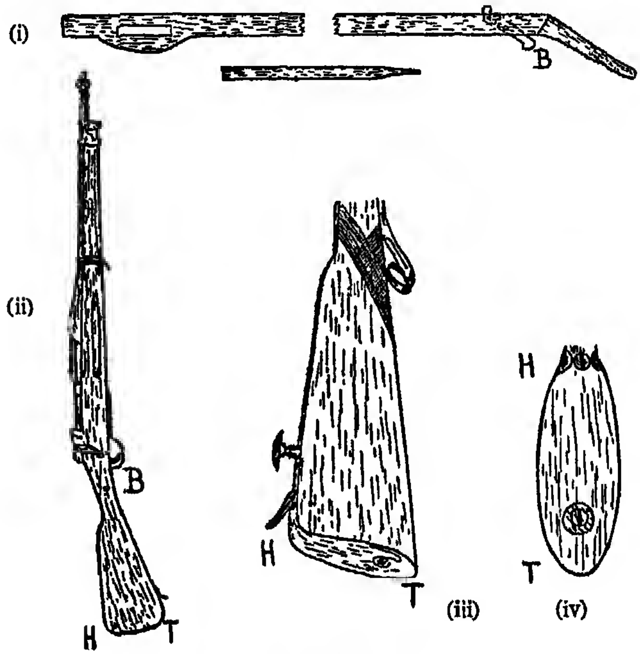


FIG. 43.
(i) Malabar crossbow, and harpoon butt
(ii) Rifle
(iii) Butt of bullet-shooting crossbow
(iv) Butt-plate of bullet-shooting crossbow
B, bend in stock; H, heel; T, toe.

The stock of the early crossbow was not placed against the shoulder, but was held tightly under the right arm pit, or rested on top of the right shoulder. The butts of early hand guns also were not placed against the shoulder, but were held by the hands or placed on top of the shoulder. A heavy recoil cannot easily be taken when the weapon is held with the hands or under the arm pit or on top of the shoulder, and aiming is difficult when the weapon is held in any

of these ways. The stocks of some crossbows and most hand guns are therefore shaped so that they can be placed against the shoulder; and part of the recoil can then be transmitted by the butt end to the shoulder. When the stock is bent, aiming becomes easier. The butt ends of crossbows and early guns were often much larger than the soles of the foot, and did not much resemble a sole. But later crossbows and guns have butt ends which resemble the sole fairly closely both in size and shape, *Figure 43*. As has been stated, the "toe" of the butt corresponds to the wielder's toe, and its "heel" to his heel; and the curve between the toe and heel of the wooden butt reproduces fairly closely the curve between the human toe and heel, or instep. The prototype of the butt end is evidently the sole of the wielder's foot.

The sole of the wielder's foot is usually protected by the leather sole of his shoe or boot; and this may have nails or plates of some kind on it to prevent abrasion by the ground. Similarly to prevent the butt end of a crossbow or gun being damaged through contact with the ground, it is often covered with a heel-plate which may be of ebonite, brass, steel, or other hard material. Makers of guns complain that wielders sometimes use them like walking sticks, placing the butt ends on the ground as they walk, and thus damage and jar the weapons.[5] Obviously, the purpose of a heel-plate is very similar to that of the sole of a boot; and the prototype of the heel-plate is evidently the sole of a shoe, or boot, or sandal (Rules 3 and 4). But the human prototype of the sole of a shoe or boot or sandal is the skin of the sole of the foot, and the leather sole is merely a mechanical extension of the skin of the human sole. Therefore the human prototype of the heel-plate is the skin of the sole of the wielder's foot.

A felt or rubber pad is sometimes fastened to the butt end of a shot gun or rifle, to help to take the shock of the recoil. Nowadays, the sole of the shoe of a marathon or cross-country runner when there is much road work is often

5 e.g., Major Sir Gerald Burrard, Bt., D.S.O., R.F.A., *The Modern Shotgun*.

heavily padded with soft rubber to take the shock of the impact of his foot on the ground. The pad on the butt evidently has the pad on the shoe as a prototype. When the heel-plate is on the ground it is horizontal but when placed against the shoulder is turned through a right angle compared with its position when on the ground. Since the curve of the heel-plate fits the curve of the shoulder, it is evident that the instep and the curve of the shoulder are closely related biologically.

The butt of a well made shot gun is not quite in the vertical plane through the rib of the barrels, but is bent slightly to one side or the other. It is placed out of the line of the barrels, in order that it may not be necessary to bend the head over the gun too much when aiming. For a right handed shooter the butt is bent to the right, or is "cast-off"; and for a left handed shooter is bent to the left, or is "cast-on"; and the amount of cast-off or cast-on depends on the physical peculiarities of the wielder for whom the gun is made, and on his methods of shooting.[6] When a butt is cast-off or cast-on, the butt must be bevelled, or chamfered, or only one edge will meet the shou [illegible]
sponding to cast-off, cast-on, and chamfering can easily be observed when an archer stands to shoot.

If an archer places both feet together, he may overbalance when shooting, and to obtain a firm base he places his feet apart, the distance apart varying with the type of bow and method of shooting adopted by the archer. If he is right handed, the effect of the recoil will be to lift his left foot and cause his butt to be formed mainly by the right foot. Since his right leg is not directly under his body, it is "cast-off" from the line of the stock of his body. Also, because his foot is not directly under his body, the sole of his foot is "chamfered", that is the inner edge of his sole is slightly nearer than its outer edge to the centre of his knee. If the archer is left handed, then the opposite effects will be seen, and his left leg will form the main part of his butt, and be

[6] Major Sir Gerald Burrard, Bt., D.S.O., R.F.A., *The Modern Shotgun*.

slightly "cast-on", and his sole will be "chamfered" in the opposite way to which it is chamfered when shooting right handed.

A gun stock is so fashioned that its butt end is at right angles or nearly at right angles, to the barrels.[7] The soles of the archer's feet also are at right angles, or nearly at right angles, to his fore-legs, or parts of the legs below the knees. But an archer may stand with his right foot slightly forward and out of the plane of the bow, and the sole of his right foot then will not be quite at right angles to the fore-leg. Similarly, the butt end of a gun may be so fashioned that it is not quite at right angles to the barrels.

Usually the soles of an archer's feet are not parallel and he stands with his toes farther apart than his heels; and the butt end of the archer is therefore usually twisted over. A well made gun stock similarly is twisted over, that is, the toe of the butt is more "cast-off" than the heel.*

It is clear that the human prototype theory fully accounts for the forms and shapes of the butts and butt ends of rifles and shot guns, and for the variations in their forms and shapes. Their forms and shapes can be seen to correspond to those of the human butts and butt ends formed by the legs and soles of the feet of an archer. Many and various types of butts and butt ends are formed by archers, depending on the types of bows and methods of shooting adopted by the archers; and, similarly, many and various types of butts and butt ends are made by gunsmiths, depending on the purpose of the weapons and on the physical peculiarities and methods of shooting of the wielders for whom the weapons are made.

When an archer stands to shoot, a pole or rod device is formed by the left arm and right arm and chest, which keeps the bow away from the body, and keeps the bow and strings apart as the strings are being drawn. This device is formed mainly by the legs and trunk when the archer lies down to

[7] W. W. Greener, *The Gun and its Development*.

* The usual "cast-off" is $\frac{3}{16}''$ for heel and $\frac{1}{4}''$ for toe—W. W. Greener.

shoot. The human parts also form a contrivance by which the missile can be elevated or depressed when it is desired to change the aim. The pole or rod device always points approximately along the direction of the missile, and some kind of directing device is perhaps formed as well. Many other devices are also perhaps formed, which have escaped the author's notice. It is, of course, difficult to see and distinguish these devices in the bow and arrow machine, for none of them are mechanized.

In the crossbow machine the pole or rod device is partly mechanized, and holds the bow and strings apart when the strings have been drawn, and the weapon can then be carried without the human parts directly helping to form the device. But when the weapon is being aimed, the crossbowman again helps to form the device, as his left arm is stretched forward along the stock; and it seems therefore that the human parts are not fully released from the need for forming the device.

The rod or pole device cannot easily be distinguished in the crossbow machine from the wooden stock device, for the wood of the stock has to serve as a stock to support the barrel, and as a pole or rod device to keep the bow and strings apart.

The partial mechanization of the human stock by the fitting of the wooden stock to the archer's bow has the effect

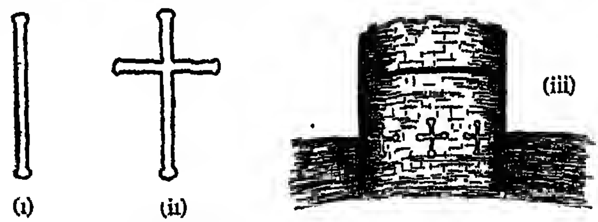


FIG. 44. LOOPHOLES

(i) Vertical opening for archer
(ii) The same with a horizontal opening added for use by a crossbowman
(iii) Goblin Tower, Chester City Walls, XIIIth cent. (restored), showing loopholes for crossbowmen

of turning the bow arms and strings through a right angle

(Rule 10); for the archer's bow is in a vertical plane but the crossbowman's bow is in a horizontal plane. One result of this turning of the bow arms through a right angle has been to produce the cruciform loophole, called arbalestina[8] or balistraria, often made in the walls of a castle or other mediaeval fortress. The archer needs a vertical but the crossbowman a horizontal slit or loophole through which to shoot. The cruciform loophole however can be used both by the archer and the crossbowman, *Figure 44* (*ii*), (*iii*).

The turning of the bow arms through a right angle, when the stock is partly mechanized, reveals that the offensive machine has two planes; and that the parts and devices of the offensive machine are contained as much as possible in one or other of two planes at right angles to each other, and that all actions take place, as well as can be arranged, in one or other of these planes. The planes may be called the direction and elevation planes.

The planes can be quickly discovered and distinguished, by looking first at the bow and arrow machine and then at the crossbow machine. The bow and strings of the ordinary bow and arrow machine are in a vertical plane, which is the direction plane. The bow and strings of the crossbow machine are turned through a right angle compared with those of the ordinary bow and arrow machine, and lie in the elevation plane.

As the crossbowman aims, his direction plane includes the quarrel or bolt, the wooden stock, the trajectory line, and the target, all as nearly as possible. The wooden stock cannot be contained wholly in a plane nor can the bolt, but the axis of the bolt lies exactly in the plane. The whole of the target is not contained in the plane, but the point where it is struck lies exactly in the plane. If the target is fixed, the direction plane is also fixed; but if the target moves, the direction plane will turn as the crossbowman changes the direction of his aim. This plane can be conveniently called the direction plane because it shows the direction of the aim, or shows the direction in which the missile is sent.

[8] Sir Ralph Payne-Gallwey, Bt., *The Crossbow*.

The crossbowman's bow and strings do not lie in the direction plane, but lie in a plane at right angles to it. More correctly, they lie on a parabolic surface. If there was no gravitational force, when the quarrel was loosed it would travel in a straight line along a flat surface which would include the bow arms, strings, trajectory line, and point where the target was struck. But because of gravitational force the crossbow must be given an elevation and the quarrel be aimed higher than the target; and when the quarrel is loosed instead of travelling in a straight line along a flat surface, it travels in a parabolic or elliptic curve along a parabolic or elliptic surface. The bow arms and strings lie on this surface approximately. This surface may be called the elevation surface or, conveniently but not quite so accurately, the elevation plane.

The quarrel of the crossbow lies both in the direction plane and in the elevation plane, and is shot along their line of intersection. This line has the form of part of a parabola.

When the archer holds the bow horizontally or shoots lying down, the bow arms and strings then lie in the elevation plane, and compared with their positions when the bow is held vertically are turned through a right angle, and are transferred from the direction plane to the elevation plane. When a wielder uses a crossbow instead of a bow and arrow, he transfers the bow and strings from the direction plane to the elevation plane.

There are many styles of shooting in archery; but the archer always seems to do his best to keep all parts of the machine as nearly as possible in either the direction or elevation plane. Thus in *Figure 35* the archer's stock and legs are as much as possible in the direction plane; and his arms are also placed as much as possible in this plane.

Parts of the offensive machine may lie both in the direction plane and in the elevation plane. Thus, in *Figure 35* the arrow lies in the direction plane and in the elevation plane. The arms and hands also lie in both planes. The elevation plane, which includes the arrow and arms and hands is elevated or depressed as the arrow is aimed higher

or lower, the right elbow being depressed or raised and the left hand being raised or lowered as the elevation is increased or decreased. If the archer were to hold the bow horizontally, the bow and strings would then also lie in the elevation plane, but not then in the direction plane.

The body of an archer cannot be kept in a plane, because it has three dimensions. Similarly the hands or feet or other parts of the body cannot be placed in a plane. But it does not follow therefore that the human parts and devices of the offensive machine cannot be placed in a plane; for, as has been pointed out, the parts and devices of the offensive machine are not the same as parts and devices of the body.

The only parts the archer in *Figure 35* has not tried to squeeze into one or other of the planes are his feet, which seem to disobey the rule that they should be in the elevation or direction plane. Possibly their positions can be explained as follows:—

The elevation plane forms, or would form if it were not for gravity, a plane surface parallel to the ground surface. The ground, it has been explained, forms a kind of return circuit for the trajectory; and therefore is related to and may be an extension of the elevation surface, or conversely the elevation plane may be an extension, a little higher up, of the ground plane; and parts and devices can be transferred from one plane to the other. If this or some similar explanation is not correct, it may be necessary to postulate three planes in one of which any part or device must lie, namely the direction plane, the elevation plane, and the ground plane. The archer's feet lie on the ground plane; and it seems best to regard them as transferred with that plane from the elevation plane, and to regard the elevation and ground planes as extensions of each other. When an archer or rifleman lies down to shoot, an attempt seems to be made to bring the elevation and ground planes together.

The bow and strings of the bow and arrow machine cannot be placed quite in the direction plane unless the arrow is shot through the handle, but must be placed a little out of the plane. When the arrow is shot through the handle, this

aberation is corrected. Similarly in the crossbow machine the bow and strings cannot be placed quite in the elevation plane because the quarrel cannot be shot through the bow; and the plane of the bow and strings therefore is slightly below the elevation plane. This aberation is corrected in the stone-bow machine with a curved stock.

The archer's left arm may be hurt by the strings brushing against it as they are released. Also the strings will experience friction and a dragging effect and will wear. To prevent hurt to the archer's arm and friction on the strings, sometimes the archer wears a bracer or gauntlet of leather or other material, or a vambrace of polished ivory or metal on his arm, and often the bracer is decorated—Chaucer's line may be recalled: "Upon his arm he wore a gai bracer." If the crossbow's bow arms were placed in the plane of the stock, the strings would scrape the top of the stock and would experience friction and a dragging effect and would wear. To prevent hurt to the top of the stock and friction on the strings the bow arms are specially shaped and then set at a slight angle to the stock, or canted, so that the strings just clear the top of the stock. The stock of the crossbow like the bracer is often decorated.

The axis of the barrel and breech of the bow and arrow machine lies exactly in the elevation plane and also exactly in the direction plane. This follows because the axis of the barrel and breech coincides with the axis of the arrow, which it has been explained lies both in the elevation and direction plane. The left arm, right upper arm, and right fore arm lie as nearly as possible in the direction and elevation planes. The bow nocks, when the bow is held vertically, lie in the direction plane, but the archer's hands which are their human counterparts lie in the direction plane and also in the elevation plane. When the bow is held horizontally, the bow nocks lie only in the elevation plane. The quiver of the archer in *Figure 35* seems to be nearly in the direction plane. As the archer turns his body the quiver turns with the direction plane and remains in it. The spare arrows under the foot seem nearly in the direction plane, and also in the

ground plane. When spare arrows are held in the left hand against the bow handle they lie in the direction plane.

The mechanical part of the trigger of the crossbow machine is in the direction plane, but the human trigger finger device formed by the forefinger is horizontal and approximately in the elevation plane.

When the axis of the crossbow machine is mechanized, the mechanical part lies in the direction plane and at right angles to the elevation plane. The axis of the Chinese crossbow machine is formed by the pivot round which the weapon is turned. The pivot is fitted to the under side of the stock and placed in a socket on a wall so that the weapon can be conveniently held and turned. This pivot must be a mechanical copy of a pivot of the human offensive machine, whose existence is thus revealed.

In a general way it may be said that direction for hitting an opponent with the fist is obtained by turning the body round an axis. How this axis is formed or where it is situated cannot easily be known. As the fists are moved, the trunk turns round an axis approximately formed by the backbone. The head swivels on this axis, but does not turn with the body, for the wielder of the fists always faces his opponent and keeps his eyes fixed on him. The way in which the body turns on its axis while the head remains almost stationary while swivelling on the axis can be well seen by standing in front of a mirror and going through the motions of using the fists against the imaginary opponent in the mirror. Direction for hitting the opponent or target is obtained by turning the body round its axis, the legs being so placed that the line from one foot to the other gives the direction of the blow or thrust. The direction in which the shot putter sends his missile is given first by the line joining the right foot to the left, but at the final moment the feet are reversed and the direction is given by the line from the left foot to the right. For archery practice, according to E. W. Hussey, "in the ideal footing, a line from the object—for all practical purposes the centre of the target—should pass

through the centre of the heels . . . "[9] If an animal or bird crosses the path of an archer, he changes the positions of his feet, if the swivelling of the body proves insufficient to make a shot convenient, so that the line from his right foot to his left foot points just ahead of the creature. Similarly, the crossbowman directs his missile just ahead of the creature by turning his body on its axis, but if the amount of the turn becomes too great he changes the position of his feet so that the line from the right foot to the left gives the direction. Small corrections as the creature continues to move can be made by turning the body on its axis.

Although it is difficult by direct observation of a human machine, like the fist machine, to discover the axis of the offensive machine, it can be noticed that one of the vertebrae of the backbone, the second cervical vertebra, is called the axis, and that this vertebra allows the head or skull to turn relatively to the lower vertebrae. It is probable therefore that the axis of the human offensive machine is formed by the backbone or spine, with the second cervical vertebra, or axis, forming turning mechanisms. If this is so, then any pivotal contrivance of a weapon, like the pivot of the Chinese repeating crossbow or the tripod of a machine gun, is a crude mechanical copy and extension of the axis of the backbone. Further, the first cervical vertebra, the atlas, allows the head to nod. Since the head is raised or lowered as elevation is increased or decreased, mechanisms of the atlas are probably prototypes of certain of the elevating and depressing mechanisms of weapons. It can also be noticed that the axial skeleton of the body is formed mainly by the backbone and skull. This supports the belief that the axis of the offensive machine is formed by the backbone.

The axis of the offensive machine is sometimes partly mechanized by means of the turning pin or axis of the siege crossbow, *Figure 60.* This is a large and heavy weapon, weighing about 18 lbs., usually placed upon a parapet or pivoted on a small tripod.[10] The turning pin is probably a

9 The Rev. Eyre W. Hussey, *Badminton Library.*
10 Sir Ralph Payne-Gallwey, Bt., *The Crossbow.*

mechanical counterpart and crude copy of the human pivot

The axis of the rifle or shot gun machine is mechanized when the weapon is placed on a stand, as for example when an instructor places the gun on a stand which is so made that the direction and elevation of the gun can be fixed as desired to show how it is sighted on to a target. The axis is sometimes formed by the left arm, as when a rifleman lies on the ground with the weapon in his left hand and the elbow on the ground. The rifle can be slightly turned round the pivot of the elbow; but the direction cannot be much changed unless the rifleman moves his body. The line joining the feet, when shooting lying down is not directed towards the target, but seems to be turned through a right angle. The axis of the machine gun machine is usually partly mechanized by a tripod or other type of stand. The tripod is a modified mechanical copy of the elbow device described above. The early hand gun machine's axis was usually partly mechanized by means of a stand, which in the case of the large culverin and the arquebus consisted of a forked stick.

If the simple sling is whirled at the side of the body, the whirling plane is in the direction plane, which includes the strings, pouch, and centre of gravity of the missile. The body cannot be placed in the plane, but is placed as nearly in it as possible. The positions of the elevation plane can be known easily only while aim is being taken and while release is being effected. When taking aim the left hand holding the pouch and missile is stretched forward so that the line of the strings from the right hand to the left gives the intended elevation. The hands, strings, pouch and missile are then in the elevation plane, as well as in the direction plane. As the missile is released, the right hand holding one string goes forward, and the strings tend to come into a straight line and lie along the elevation plane.

The elevation plane, it seems, during the whirling of the missile, revolves approximately round a horizontal axis through the right hand, so that the strings and pouch and missile are always in the elevation and direction planes.

If the sling is whirled above the head and no elevation is given, it is whirled in a horizontal plane which is the elevation plane. But when an elevation is given to the missile the elevation plane is tilted at an angle to the horizon.

The direction plane it seems revolves with the strings about an axis formed by the axis of the body. It is stationary during the aiming movements; but during the whirling movements the vertical direction plane revolves so as always to include the strings and missile, but except at two moments in each revolution does not include the target. The missile is released after the direction plane has revolved one or more times, when the plane is at right angles to its aiming position; and the missile is thrown at right angles to the direction plane. The plane continues to revolve after the missile has been released, and is brought to rest once again in the aiming position; the right hand, and strings which then come into a straight line, and pouch between the two strings, lying in the direction plane and pointing along the trajectory to the target. (The missile must be released when the strings are practically at right angles to the line joining the body to the target, for on release the missile flies off at a tangent to the curve it was describing).

It appears therefore that when the sling is whirled at the side of the body the direction plane is fixed in direction, but the elevation plane revolves about a horizontal axis approximately; but conversely, when it is whirled above the head, the elevation plane is fixed in direction, and the direction plane revolves about a nearly vertical axis. The axis is not quite vertical because the slinger leans backwards to keep it at right angles to the elevation plane.

If the sling is whirled above the head, the target is included in the direction plane only at two moments, the first moment being when the missile is being aimed, and the second as it is released; and when it is whirled at the side of the body, conversely, the target is included in the elevation plane only when the missile is being aimed and when it has just been released. This shows that the target is not always included both in the direction plane and in the elevation

plane at all times. It seems that whenever the hands of a wielder are reversed in direction the target temporarily and during the reversal of the hands is not included in one of the planes. Thus, for example, when the wielder of the fists is bringing his rear fist to the front to deliver a swinging blow, the direction plane which included his fists does not include the target. The line of the intended blow is shown by the line joining the fists. This line is suddenly reversed in direction when the rear fist is brought to the front, being reversed along the elevation plane's surface when a swinging blow is being given, but being turned over in a vertical plane when a thrusting blow is being given. When therefore the line from the hands is being reversed the target is temporarily not in one or other of the planes.

When a sling is being whirled the direction of the blow seems to be reversed as often as the strings are whirled. The movements of the hands are very complicated and are quickly performed; but the left or free hand seems to imitate the movements of the right hand which holds the string ends, and it can be conjectured that they are so placed at any moment that the direction line is from one hand to the other, this line being reversed twice in each revolution of the strings, and not once as the line joining the fists is reversed when the body makes a half turn.

The direction and elevation planes can be observed fairly well when some field athletic sports machines are in action.

The elevation plane of the hammer throwing machine is very easily seen, for it is the plane in which the weapon is whirled. During the whirling movements the elevation plane includes the arms of the wielder, the hands and stirrups, wire and head of the hammer. The direction plane always includes the wire and head, but revolves and does not include the target except twice in each revolution. After release it includes the body, hammer, trajectory, and place where the head hits the ground, or target.

The elevation plane of the javelin throwing machine includes the javelin at all times. The elevation of the plane is shown by the angle the javelin makes with the ground.

During the aiming movements the left arm and right arm point with the javelin to the target and are both in the elevation and direction planes. The hands and arms make a half turn along the surface of the elevation plane as the right hand comes forward to deliver the thrust. As the hands are reversed and the half turn is made the direction plane revolves through two right angles.

The elevation plane of the discus thrower is fairly easy to see It includes the centre of gravity of the discus, and both hands and arms. The arms are outstretched during the whirling movements, and the elevation plane usually slopes downwards to the side next to the discus. The elevation plane of the shot putter includes the centre of gravity of the shot, the hands and the arms. Its inclination is shown by the line from one hand to the other. The hands swing round in the elevation plane as the half turn is made, and the direction plane turns through two right angles as the half turn is made.

Field athletic sports machines are very slightly mechanized. It cannot be expected therefore that the planes and their positions can be easily seen or studied directly; but the existence of the planes is clear beyond a doubt.

The fist machine is not mechanized at all. It might therefore be thought the planes cannot be seen; but after a study of mechanized machines, they become fairly evident, and some general statements can be made about them.

The direction plane of the fist machine includes the fists, axis of the stock, and line from one foot to the other. As the half turn is made to bring the rear fist to the front to deliver the blow, the fists are reversed along the surface of the elevation plane, and also along the direction plane. The point where the opponent is hit is in the direction and elevation plane. If the wielder of the fists is inexpert or clumsy probably parts of the offensive machine do not move always in one or other of the planes. Even the expert wielder sometimes transgresses, but probably an expert wielder of the fists, although he may be unaware of the existences of

these planes, does try to keep all parts and perform all actions in them.

CHAPTER 34

THE BOW AND STRINGS

THE bow arms are fastened to the stock by thongs, cords, metal bands, or other types of mechanical clasps, *Figures 39, 54, 61.* The clasps correspond to the human clasps formed by the left hand of an archer as he holds the handle of his bow. They must also correspond to the human fastenings which hold the wielding arms to the human stock. The archer's left hand and fingers therefore besides forming a barrel for the handle form also clasps which are transferred copies of the human clasps which hold the wielder's arms to the stock of his body. The mechanical clasps which hold the bow arms to the wooden stock are therefore mechanical reproductions or extensions of the human chest fastenings. The mechanical clasps are very crude and elementary embryos of the human fastenings.

The bow arms of the crossbow are mechanical or artificial reproductions of the arms of the wielder. Reasons for believing that bow arms correspond to the wielding arms have been given in the chapters on the bow and arrow machine, and need not be further elaborated here, although it may be pointed out that in the crossbow machine the bow arms are usually concave to and in the same plane approximately as the wooden stock; but sometimes the concave side, before the strings are drawn points away from the stock. The crossbow's bow arms compared with the wielder's arms are reversed, for the human arms when outstretched are concave to the front and in a horizontal plane and therefore at right angles to the direction of the stock and butt of the body, as can be seen at once by bringing the outstretched arms forward until the fingers touch.

At the ends of the bow arms are the bow nocks for holding the ends of the strings. On many crossbows the nocks are well formed; and, as has been stated, the projections over

which the strings are passed are called the "thumbs"; and a bow nock holds a string end in much the same way as if it were passed over the thumb of a hand. The bow nock is easily recognizable as corresponding to a hand at the end of an arm. *Figure 45* shows the "thumbs" of a bullet-shooting crossbow, and the methods of attaching the bow strings. The "thumbs" are not similar, but face opposite ways, as the human thumbs face opposite ways, one being a left handed thumb and the other a right handed thumb.

The strings of a crossbow, like those of the bow and arrow, correspond to the strings of the wielding arms. In machines shooting arrow types of missiles, the strings are

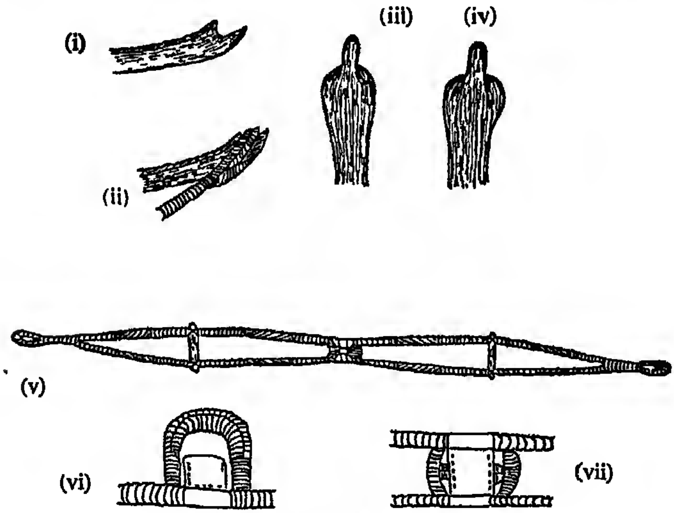


FIG. 45.
(i) Thumb of a bullet-shooting crossbow
(ii) The thumb, with strings fitted
(iii) Left thumb
(iv) Right thumb
(v) Strings of bullet-shooting crossbow
(vi) Pouch of bullet-shooting crossbow
(vii) The pouch open, seen from the front

single, but the types which shoot a ball or pellet usually have double strings. The strings are made stronger as a rule than those of an ordinary bow and arrow, but often made

from similar materials. Some crossbow strings like those of the Chinese repeating crossbow are made of catgut. A few crossbows have chain strings.

The strings are usually wrapped at the middle with twine or cord to prevent the strings being worn as they slide along the stock and to prevent abrasion by the butt of the arrow. They are usually wrapped also near the bow nocks, *Figures 39, 45, 54, 59, 61.*

Wrapping or binding formed by a length of cord is automatically rifled. The strings also, when they are twisted are rifled. The rifling of the crossbow machine is thus partly on its strings. That of the ordinary bow and arrow machine is similarly partly on its strings; and the rifling of the strings is impressed on the right hand fingers as they hold the strings, that is on the back part of the barrel. The riflings of the ordinary bow and arrow machine are therefore partly mechanized. Whenever twisted strings are used, necessarily and automatically rifled grooves are formed on the strings, and machines having such strings have their riflings partly mechanized by means of them. If for example the strings of a sling are twisted, the riflings of the machine are partly mechanized by means of the string spirals, and the spirals will be impressed on the hands holding the string ends, and the barrel formed by the fingers holding the string ends will be rifled.

The strings of the prodd or bullet-shooting crossbow are double; and possibly reproduce certain features of the string-like components of the wielder's arms better than they are reproduced by archer's strings. The strings of pellet bows are usually double, and resemble those of prodds.

The double strings of a prodd are kept apart sometimes by little bone or ivory pieces, which probably are mechanical extensions of certain bones of the arms. They are at right angles to the plane of the bow arms, *Figure 45* (*v*).

The pouch of the bullet-shooting crossbow is a modified type of pellet bow or sling pouch; as is evident, because the strings of the crossbow are fastened to the pouch in much the same way as the strings of a pellet bow are fastened to its pouch; the string ends opposite the pouch are held by the

slinger's hands or pellet bow's nocks, and those of the crossbow are held by the mechanical hands or nocks; the material of the pouch of the crossbow is usually of leather, and that of the pouch of the sling is also frequently of leather.

The missile is a small spherical bullet of lead, baked clay, stone, or other hard substance, about the size of the common marble. It is held in the little leather pouch, which is shown in *Figure 45*. The strings behind it hook over the metal finger. They cannot be drawn by hand, as the bow which is of steel is too powerful. Those of the nineteenth century bullet-shooting crossbow are drawn by means of a long lever which is imbedded in the top of the butt. It is shown raised in *Figure 46*. As it is raised the part of the lock above the

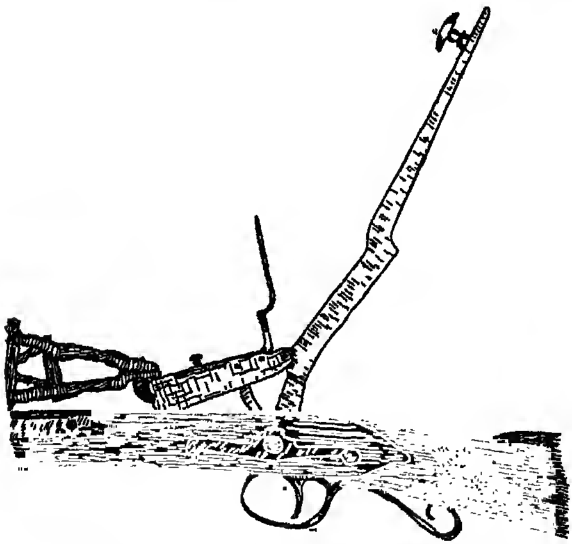


FIG. 46. BULLET-SHOOTING CROSSBOW, WITH LEVER RAISED TO DRAW THE STRINGS

stock is pushed forward until the metal finger can be hooked under the strings at the back of the pouch. The pouch is then open. The bullet is placed in it, and the button at the end of the lever is pressed with the palm of the right hand

until the lever is flush with the stock and engaged in a catch at the end of the butt. As the lever is pressed down, the lock with its catch is drawn back until it comes into engagement with the seers inside the stock, and is connected to the trigger. The pouch closes round the bullet as the pouch is drawn back, until it is very tightly held. When the trigger is pulled, the metal finger releases the strings, and the bow arms straighten and pull the strings into a straight line, throwing the bullet forward through the metal front sight, below the bead. A peculiar feature of this crossbow is that the main part of the lock is on top of the stock, and not inside it as in the shot gun and rifle. The weapon was used mainly for shooting small game like rooks and rabbits. It has an advantage over the gun of being almost silent in action.

A crossbow is usually too powerful for the wielder to be able to place the strings on unaided, so a "bastard" string is first placed over the bow nocks or just short of them, and is drawn by the lever, after which the real strings can be slipped on and the bastard string be removed.

CHAPTER 35

THE LOCK (CROSSBOW)

THE strings of early crossbows after being drawn were slipped over a projection on the stock or into a groove cut transversely in the top of the stock. While drawing the strings the crossbowman's fingers curled round them and formed a catch to hold and draw them. After being slipped over the projection or into the groove the strings were no longer held by the human catch, and were then held by the mechanical catch formed in a crude and elementary manner by the projection or front edge of the groove. The mechanical catch was complementary to the human catch and replaced it when the strings were fully drawn.

On many modern types of crossbows the catch which holds the strings in the drawn position is formed much as on the early crossbows simply by a transverse groove in the stock. The strings of the Fan crossbow of West Africa, for example, are slipped into a transverse groove cut in the top of the stock,[1] *Figure 41*, and the simple catch formed by the groove acts in much the same way as the catch formed by the crossbowman's fingers when holding the strings in the drawn position. The mechanical catch must be of a similar type to that formed by the crossbowman's fingers, since it takes over the work of holding the strings from the fingers, and if there were any considerable difference in types, it could not easily or smoothly take over this work as the crossbowman drops the strings into or over it. The Mpongwe, Mandingo, Yoruba, Benin, and Ba-kwiri crossbows of West Africa also have elementary mechanical catches of the Fan type.

The strings of the Chinese repeating crossbow are held in

[1] H. Balfour, M.A., F.R.S., *Journal of the African Society*, 1909; The Rev. J. G. Wood, M.A., F.L.S., etc., *The Natural History of Man.*

Fan type, but the strings are drawn with the help of a goat's foot lever.[2]

A catch to hold the butt of the crossbow's arrow, quarrel, or bolt, after the manner in which an arrow's butt is held by an archer is found on most mediaeval and many modern types of crossbows; and is formed by the revolving nut, or barrel, of ivory, wood, or other material, partly sunk in the stock at the place to which the strings are drawn, *Figures 50, 52, 54.*

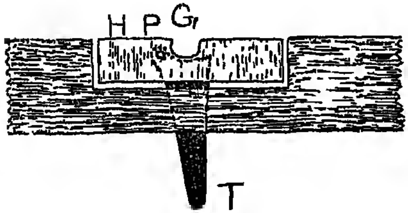


FIG. 49.

LOCK OF BURMESE CROSSBOW

Horniman Museum

The nut is shown in *Figure 50.* It is cut out of a cylindrical piece of ivory or other material, and has a hole bored

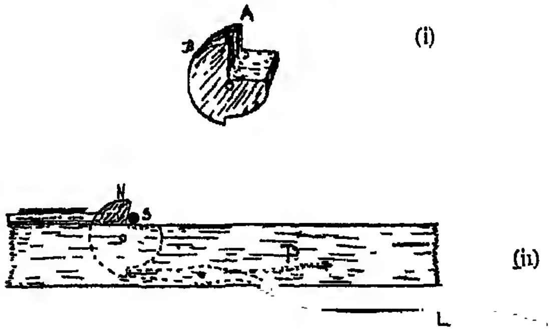


FIG. 50.
(i) Nut, with two "fingers" A and B
(ii) Diagram of nut and lever
A, arrow; L, lever; N, nut; P, trigger spring; S, strings

through its axis. Parts of the cylinder are removed so that two crude types of fingers A and B are formed between which the tapered butt of the quarrel can be pressed and

[2] H. Balfour, M.A., F.R.S., *Journal of The African Society*, Vol. VIII, No. XXXII, July 1909.

held. The nut is notched underneath for engagement with the lever or trigger L. It is sunk rather more than half its depth into the top of the stock; and therefore there is no tendency for the strings to pull it out of the stock, and indeed there might be no need for a peg or bolt to be put through the hole in the nut to secure it to the stock, and it would revolve about its axis naturally. Hence often the nut is secured merely by a cord of sinew or other material passed through holes in the sides of the stock and the hole in the nut.

Before the bow is drawn the nut is revolved into its correct position to receive the strings. Its lower part is then in engagement with the lever, and its fingers are nearly upright and pointing slightly backwards. As the strings are drawn they slip over the circular edges of the nut and are then caught behind its fingers.

A small spring P inside the stock presses on the top of the lever and prevents the lever being accidentally jolted out of engagement with the notch of the nut. To release the strings the long lever is squeezed up against the under side of the stock. This causes the other end of the lever to come out of engagement with the notch of the nut, which is then free to revolve. The strings force down the fingers of the nut until they are flush with the stock, and engage the butt of the arrow A and drive it along the barrel.

Writers on the crossbow often call the two top parts of the nut the "fingers" of the nut,* evidently because of the resemblance of the device to the fingers, and resemblance of its actions to the actions of fingers when holding and releasing bow strings. Since the mechanical fingers of the nut resemble the device formed by an archer's fingers for holding and releasing the strings and their actions copy those of the archer's fingers, the prototype of the nut is evidently the device formed by the human fingers to hold the strings of a bow (Rules 1 and 4).

The mechanical fingers of the nut hold the strings in much

* e.g., "The butt of the bolt is placed against the bow strings between the fingers of the nut."—Sir Ralph Payne-Gallwey, Bt., *The Crossbow*.

the same way as the archer's fingers hold the strings when a two-finger catch is used, one finger being above the butt of the arrow and the other below it, *Figure 51.*

The revolving nut therefore has types of fingers which hold the strings and the butt in almost the same way as the fingers of an archer hold the strings and butt of an arrow; and it is evidently a device by which the finger hold of an archer can

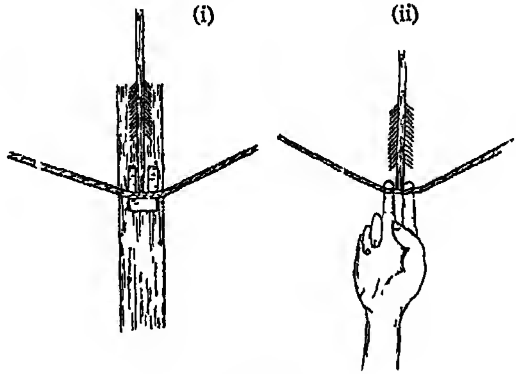


FIG. 51.
(i) Strings and arrow of crossbow held by fingers of nut
(ii) Strings and arrow of bow held by fingers of hand.

be applied in a mechanical form to hold the strings and butt of the missile of a crossbow. The nut besides forming a catch device to hold the strings and a device to hold the butt forms other devices, some of which will be described and studied later.

The crossbow's quarrel is not drawn with the strings, but is placed in position after the strings have been drawn. That is, the missile is not placed in its barrel and breech at the beginning of the drawing movements but at the end of the movements, the action being transferred from the beginning to the end of the movements (Rule 9).

The strings of a prodd or bullet-shooting crossbow are held by a metal catch, which seems to be a mechanical copy of a bent forefinger or thumb, *Figure 53.* Its size varies considerably on different crossbows, but it is always smaller than the

forefinger or thumb, and is distorted in size to resemble somewhat a very short and stumpy bent forefinger or thumb. This type of catch resembles the type of catch formed by an archer when he draws the strings with the forefinger or thumb.

Release of the strings from a transverse groove is often effected simply by the crossbowman pushing them out with his fingers. The release of the Ba-kwiri crossbow, for example, is effected in this way.[3] But this method of release disturbs the aim; and often instead of the fingers acting directly against the strings, they act indirectly by pushing up a peg through a hole in the stock immediately under the groove. That is, the fingers are transferred to the lower end of a small peg which then becomes an extension of the finger device; and the strings are pushed out by the device formed by the crossbowman's finger and its artificial extension. A modification of the peg device is seen in the Burmese crossbow, *Figure 49*. The peg or trigger T is hinged in the horn block H at a point P, and is made to rise and push out the strings from the groove G when the finger presses against its side, the finger action being applied at right angles to the trigger, and the direction of its action is thus turned through a right angle compared with its direction when a peg is pushed from underneath (Rule 10). It can be noticed that the finger action is similarly applied at right angles to the trigger of a gun. The Burmese peg is a type of mechanical trigger, and the principles of its actions are similar to those of the trigger of a shot gun or rifle, of which it is a prototype. Since the human prototype of the wooden peg is the finger device, the human prototype of the trigger of a gun must be the device formed by the wielder's trigger finger.

The strings of the Malabar crossbow are released by pulling on a short trigger, Figure 52;[4] but the trigger does not act directly on the strings, but acts on the notch at the bottom of the revolving nut; and the trigger action of the finger is

[3] Dr. F. Von Luschan, *Zeitschrift Für Ethnologie*, 1897, page 204.
[4] James Hornell, F.L.S., F.R.A.I., South Indian Crossbows, *Journal of The Anthropological Institute*, Vol. LIV., 1924.

transferred in succession from the finger to the end of the trigger in engagement with the nut, then immediately to the notch in the nut, then across the nut to the fingers of the

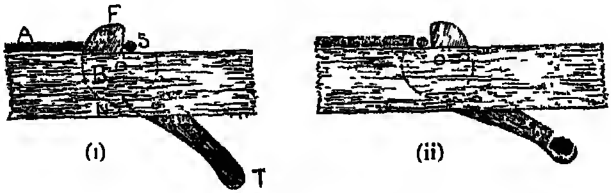


FIG. 52.
ACTIONS OF LOCK OF MALABAR CROSSBOW
(i) Trigger engaged with nut
(ii) Trigger pulled, and nut and strings set free
A, arrow; B, nut; F, finger of nut; S, strings; T, trigger.

nut, which release the strings when the finger action is applied. Transference of the actions, it can easily be seen, takes place in accordance with Rules 7 and 8. The fingers of the nut copy in a distorted but sufficiently effective way the action of the crossbowman's finger as it is applied to release the strings. The crossbowman's finger action is modified compared with the action that would be required if the strings were directly held by the fingers, modification being possible and necessary because of the interposition of mechanical devices between the human fingers and the strings.

The lock of the gun evidently is now taking shape. Locks of shot guns, rifles, machine guns, and other guns, differ from the locks of the Burmese and Malabar crossbows mainly in having more levers and springs and other devices, between the trigger finger and the device which immediately sets free the power.

The mediaeval crossbow usually has a long lever or tiller to engage the notch of the nut; and instead of being pulled it is pressed up against the under side of the stock and thus forced out of engagement with the notch, *Figure 50*. The nut then revolves and sets free the strings. The action is harsh and jerky and liable to upset the aim.

Since the long lever or tiller is pressed upwards and the trigger of the Malabar or Burmese crossbow or rifle or shot

gun is pulled towards the wielder, the direction in which the finger action is applied when the long lever or tiller is used is turned through a right angle compared with the direction in which it is applied when the triggers of these other weapons are pulled (Rule 10).

The wielder of a shot gun, rifle, Burmese or Malabar crossbow releases the power to drive forward the missile by tightening his hand and fingers, or clenching his fist more tightly. This action is opposite to that of the archer, who, to release the power unclenches his fist, and relaxes his hand and fingers which just previous to the release were taut and partly clenched. The action, however, is similar to that of the wielder of the fists, who, at the moment he delivers the blow tightens his fist. The reversal of the actions when certain types of weapons are being wielded is in accordance with Rule 11.

As a crossbowman draws the strings into a transverse groove his fingers are curved and taut; but when the strings are slipped into the groove his fingers immediately become relaxed and straighten. The elementary mechanical fingers formed by the front of the groove as they receive the strings tighten, and are already curved slightly backwards to prevent the strings rising and escaping. The tightening and curving actions are thus transferred from the human to the mechanical fingers at the moment the strings are slipped into the groove. To release the strings, the sequence of these actions is reversed, for the fingers of the crossbowman must, as they lift out the strings, again become taut and curved. Immediately after release, the mechanical fingers are released from strain.

When the strings are drawn into the groove in the ivory block in the stock of the Burmese crossbow, the block is under much strain, and the slightly curved front of the groove against which the strings press and which forms a crude mechanical finger is also under much strain. The crossbowman's finger is lightly pressed against the wooden trigger just before release. At the moment of release it curves more round the trigger and becomes taut. The trigger similarly

becomes taut and pushes up the strings. Immediately after release the crossbowman's finger becomes relaxed, and the trigger likewise becomes relaxed and indeed rattles in its socket if the crossbow is shaken.

Before the strings of the Malabar crossbow are drawn, the nut and the trigger are loose. When they are drawn they become very taut, and the flat surfaces of the nut point slightly back and thus curve slightly round the strings. The crossbowman's finger remains relaxed until the moment of release, when it suddenly becomes taut and more curved. After release the nut and trigger become loose on their pivots and the crossbowman's fingers relax and straighten, and the flat surfaces of the nut no longer curve slightly backwards.

When the lever of a bullet-shooting crossbow is raised, the metal finger, or catch for the strings, goes forward until the strings can be slipped over it. As the strings are being drawn, the metal finger becomes progressively more taut. At the moment of release it suddenly becomes relaxed, or loose, and instead of curving back points forwards and allows the strings to escape. The sequence of the actions of the metal finger is therefore the same as that of the archer's fingers.

Thus, the principles of the release actions of all the machines discussed above can be seen to be the same. Two methods of release, of which each method is the reverse of the other, are used. The finger, whether human or mechanical, just before release is curved and taut, and after release is straightened and relaxed, or before release is relaxed and at release is made taut and more curved. The reversal of one method of release compared with the other is in accordance with Rule 11, and the exact reversal of one method compared with the other shows the fundamental similarity of both methods.

When an archer releases his strings his fingers point in the direction of the blow or thrust, that is along the direction taken by the arrow. This action is copied by the mechanical fingers of the catches of crossbows which are free to move. Thus when the strings escape from a revolving nut, they

force the flat surfaces of the nut down until they point along the top of the stock, and along the direction taken by the arrow. That is they point in the direction of the blow or thrust as it is being delivered. The metal finger of the bullet-shooting crossbow similarly is forced down and points somewhat in the direction in which the pellet or bullet moves. When the strings of a crossbow are pushed out of a groove by hand, the fingers necessarily point in the direction of the thrust, since they are forced to do so by the strings as they escape, the strings acting on the human fingers in almost the same way as on the mechanical fingers formed by the flat surfaces of a nut or on the mechanical finger formed by the metal catch of a bullet-shooting crossbow.

When a shot gun is used, before release of the power the hammer, which resembles somewhat a bent forefinger and is a mechanical counterpart and extension of the trigger finger, is taut, but after release becomes loose and relaxed. It can also be said to be more curved before and less curved after release of the power, for before release it is upright but after release points down. The wielder's finger on the trigger becomes taut at the moment of release and more curved. The action of pointing in the direction of the shot is not directly performed either by the hammer or the finger which pulls the trigger, but is performed by the striker or firing-pin at the base of the cartridge, the firing-pin being part of the lock and a mechanical extension of the wielder's fingers. All parts of a lock are extensions of the human lock formed by the wielder's hand and fingers, and merely allow the human devices to act indirectly to release the power.

When a blow or thrust is given by an athlete with his shot, hammer, or javelin, similarly his fingers which were taut and curved before delivery of the blow or thrust become relaxed and straighten and point in the direction of the blow or thrust. Thus, as the shot leaves the hand, the putter's fingers which were holding the shot and curved slightly round it become relaxed and straighten and point in the direction the missile has been sent. Similarly as the javelin leaves the hand the fingers point in the direction it has been sent. The

caber tosser also points with his hands and fingers in the direction of his toss as the caber leaves his hands.

It can now be seen how a study of mechanized machines allows a better understanding of offensive machines which are not mechanized or only slightly mechanized. The facts now obtained also show that the principles of all types of offensive machines are the same, and that if a principle can be seen to be obeyed in one type of machine it can be assumed to be obeyed in all types of machines. Thus, for example, when it is noticed that the mechanical finger of one type of machine after releasing the power becomes relaxed and points in the direction of the blow or thrust, it can be known that whenever the power of the offensive machine is released, whether it be the power of the shot putting, javelin throwing, club, bow and arrow, crossbow, gun, or atom bomb machine, either the mechanical or the human fingers must relax and point in the direction of the blow or thrust. Or again, when it is noticed that the knuckles of the fist when they are mechanized by means of a caestus, boxing glove, knuckleduster, or steel gauntlet, are not released from the need for indirectly giving the blow, it can be known that human parts of the machine always indirectly give the blow. Or again, when it is noticed that advantages given by use of a club are accompanied by corresponding disadvantages, it can be known that no absolute advantage can be gained by mechanizing the offensive machine.

Figure 53 shows the mechanisms of the lock of the nineteenth century bullet-shooting crossbow. It has three seers, if the trigger is counted as a seer. A seer is described by T. T. Hoopes as "simply a bit of metal which is jammed in somewhere where things are trying to move, preventing any motion until it is withdrawn."[5] When the trigger T is pulled, the seer S slips out of the notch of the piece P into the higher notch and at the other end comes out of engagement with the finger F which then revolves and releases the strings. (The end of the seer S in contact with the finger F is bevelled so

[5] Article, The Double Set Trigger, in *A Miscellany of Arms and Armor, Arms and Armor Club, New York.*

that the pull of the strings on the finger F can overcome the force of the spring and force the seer up into a higher notch). The strings can be released, if desired, by pressing the button B. The lock can be reset simply by turning the metal finger back to its original position. This type of lock has a catch strong enough to hold the strings and at the same time allows the power to be released with very little disturbance of aim, by a gentle pull on the trigger.

A Belgian crossbow has an interesting type of lock, which seems to differ in many respects from most other crossbow locks; but, fundamentally, its principles are the same as those of the others. It has two metal fingers, which automatically drop over the strings when they have been drawn, and then grip them in much the same way as strings are gripped by an archer when a two-finger hold is used. To effect the release, a small metal trigger, connected to the catch by seers, is pulled and, "the catch tilts upwards and thus allows the bow-strings to escape from the grip of its fingers . . . and the action of the Belgian target crossbow catch is identical with that of the fingers of the archer when he releases the strings of his longbow."[6] Not only are the actions of the fingers of the catch identical with those of the fingers of the archer, the actions of the human fingers when pressing the crossbow's trigger are also similar, although reversed. The Belgian

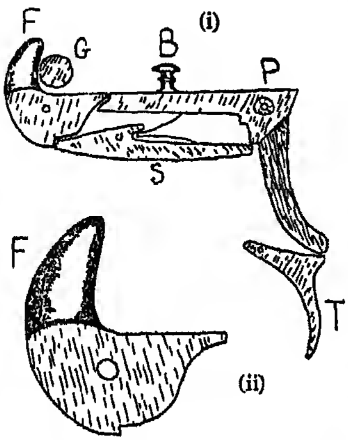


FIG. 53.

(i) Mechanisms of lock of XIXth cent. bullet-shooting crossbow

(ii) Metal finger, enlarged

B, button; F, finger; G, strings; P, piece; S, seer, T, trigger.

[6] Sir Ralph Payne-Gallwey, Bt., *The Crossbow*.

crossbow's lock is a complicated piece of machinery, but the actions of its parts merely continue and extend those of the fingers which press the trigger, so that, finally, the action of the catch itself is, "identical with that of the fingers of the archer." Clearly, the prototype of the catch is the device formed by an archer's fingers when a two-finger hold is used.

In this chapter it has been shown that the short trigger, as found on a Burmese crossbow, Malabar crossbow, shot gun, or rifle, is a mechanical extension of the trigger finger of the wielder and has as its human prototype this trigger finger device. But earlier, in the chapter on the stock, it was shown that the short trigger is an atrophied mechanical extension of the butt device formed by one of the wielder's legs, and has as its human prototype this human butt device. The results arrived at in this chapter therefore seem to contradict those arrived at in the earlier chapter. But probably there is no contradiction, and the short trigger has as its prototype both the human butt device and the human trigger finger device. The two apparently different results indeed show that there is some intimate relationship between the human butt device and the human trigger finger device. Very often it can be seen that a mechanical part or device corresponds to two apparently different human parts or devices, and it can be shown to have been developed from both devices. Thus, as another simple example, the curve of the butt end of a rifle can be seen to be derived from the instep curve near which it is placed when, say, a soldier stands with his rifle at attention. But when he shoots with the rifle the butt end is placed against the curve of his shoulder, fits this curve, and is evidently related to it and derived from it, since it is in immediate contact with it (Rules 1, 3 and 7). The curve of the butt end is therefore related to and derived from the instep curve and the shoulder curve. This shows the instep curve and the shoulder curve are closely related biologically.

In a later chapter, it will be shown that the barrel and breech and lock have been derived from various devices of the hands and fingers, and also that the mechanical parts are copies of the human reproductive organs. It will then be

seen that not only are parts of the human offensive machinery reproduced by a weapon, but that parts of the human reproductive machinery are reproduced simultaneously.

The trigger spring when a stone is thrown by hand is human, and formed only by the muscles and various other parts of the hands and fingers. Similarly, the trigger spring when the club or spear is thrown is wholly human. It is also wholly human when the bow and arrow is being wielded.

The muscles of the hand and fingers when holding the strings of an ordinary bow are under much strain. At the moment of releasing the strings a spring action of the hand and fingers occurs, the hand and fingers being allowed to spring open and to become relaxed and less curved. In order to release the strings, the taut spring formed by the muscles of the hand and fingers must be relaxed, and the hand and fingers must be straightened sufficiently to allow the strings to escape. The prototypes of the springs of the locks of guns, it will be seen, are the spring devices formed by the hand and fingers for releasing a missile.

A lock for the ordinary bow is formed entirely by the archer's hand and fingers, and has no mechanical parts. This lock has a catch, formed by the hand and fingers, for holding the strings. The type of catch depends on the archer's method of drawing the strings. When the strings are drawn by three fingers, a three-finger type of catch is formed; when by two fingers, a two-finger type is formed; and so on. The lock has a trigger, formed by the same finger or fingers forming the catch, and when the trigger is worked, the strings escape. The way in which the trigger works has already been explained, the fingers being suddenly relaxed and made less curved. The lock also has a spring action, the spring being formed by the mechanisms of the hand and fingers. To draw the strings, the spring is first made taut, and it remains taut until the moment of release, when it is suddenly relaxed.

The human lock of the bow and arrow, however, is an extremely complex piece of machinery; and its mechanisms and actions can be noticed and described only in a general way. Probably, little information can be obtained about the

lock and its actions by direct examination of the hand and fingers and their actions; but some information can be obtained by the indirect method of examining the crude mechanical imitations of some of its essential parts, which are found as the locks of crossbows and guns. Examination of locks of early crossbows gives some information about the human lock as formed for a bow and arrow. For example, after examining the catches of crossbows and their actions, it becomes evident that the human fingers when holding the strings of a bow and arrow form a catch. After examining the triggers of crossbows and their actions, it becomes evident that the same fingers which form the catch of a bow and arrow also form a trigger for the strings of the bow and arrow to release them. We conclude, therefore, that the bow and arrow has a catch and a trigger formed by human devices, and that the actions of the catches and triggers of crossbows crudely reproduce the actions of the hand and fingers when releasing the strings of a bow and arrow. Furthermore, noticing that certain locks of crossbows have springs, it becomes evident that the hand and fingers when holding and releasing the strings of a bow and arrow have a spring action. As locks of weapons become more developed, more mechanical devices are fitted to them; but all the devices can, after examination, be seen to be possessed by the lock of the bow and arrow.

When beginning to study the lock of the bow and arrow, we think it very simple. After examining the locks of weapons, we discover that the human lock of the bow and arrow is more complex than we thought. The more the locks of weapons are studied and compared with the lock of the bow and arrow, the more complex the human lock appears; and after much study we begin to suspect that very little is known about the human lock, and realize that the only way much information can be obtained about it is by comparing it and its actions with the locks of weapons and their actions.

The lock of the Turkish archer, who uses a horn groove and sefin, is not formed entirely by human devices, for the sefin, fitted to the right thumb, is a mechanical device. The

sefin, as has been explained, acts only as a catch to help to draw the strings and as a trigger to help to release them. It has no appreciable elasticity, and cannot bend, and has no spring actions of its own. The trigger spring of the lock is therefore formed entirely by human devices, and is not mechanized.

Human devices formed the trigger springs of the earliest crossbows whose strings were released simply by pushing them off a catch on the stock. Before the strings were released, the fingers rested gently against them ready to lift them quickly off the catch. At the moment of release, the muscles suddenly tightened, and the fingers became slightly more curved and pushed off the strings. The trigger spring, formed by the hand and fingers, was relaxed just before shooting and was tightened to shoot, and its action was, therefore, the reverse of that of the archer's trigger action. The Ba-kwiri crossbow's trigger spring device is also human, for the strings are released simply by the fingers pushing them from the catch on the stock, and no mechanical spring is fitted.

The lock of the Burmese crossbow has no mechanical spring, and the trigger spring is formed entirely by the hand and fingers of the crossbowman. The human spring is relaxed before shooting, and made taut at the moment of shooting; and its action compared with that of the archer is therefore reversed.

Rudimentary types of mechanical springs which help the spring action of the hand and fingers can be seen on the Fan crossbows, the springs being formed by the splits. In each type a small peg fastened to the lower limb projects up into a hole in the upper limb under the string groove, *Figure 41*, so that as the limbs close the peg rises up through the hole and pushes out the strings. In the first type, *Figure 41* (*i*), the spring from the split at the fore end of the stock helps to bring the limbs of the stock together, and partly relieves the crossbowman's hand and fingers of the need for exerting a spring action. The trigger spring formed by the split, however, is set by opening the split, and this must be done by

the crossbowman. The power of the spring, therefore, comes indirectly and primarily from the crossbowman's hand and fingers. Although, therefore, when the spring has been set, it can partly relieve the hand and fingers of the need for acting as a spring, part of the work of the hand and fingers in acting as a spring has already been performed in setting the spring. The trigger spring is in two parts, a mechanical part being formed by the split hinge device, and a human part by the hand and fingers as they squeeze the limbs of the stock together.

The mechanical part of the trigger spring is much more effective in the second type of Fan crossbow, in which the split does not extend quite to the end of the stock. Before drawing the strings the split between the two limbs is opened and a short stick inserted to keep the limbs apart. To release the strings, the stick is withdrawn from the split, which then immediately closes, and the peg goes up into the notch and drives out the strings. The trigger spring, formed by the spring from the split, is set by opening the split and inserting the stick.

It might seem that the trigger spring of the second type of Fan crossbow is fully mechanized, and that the human trigger spring action is not now needed; but, again, this is not so, because the split must be opened by the crossbowman, and his fingers perform trigger spring actions in opening it. The power for the spring from the split must come primarily from the crossbowman's fingers, and the mechanical trigger spring device merely allows the human trigger spring actions to be applied more conveniently and at a later time. The spring of the split device cannot, of course, set itself, and must be set by the crossbowman.

The use of the mechanical spring device of the split causes some modifications of the actions of the crossbowman's hand and fingers in releasing the strings, but the principles of the actions are not altered. When releasing the strings of the first type of Fan crossbow, the hand and fingers holding the end of the lower limb of the stock have a trigger spring action as they tighten and curve more round the end. The human

trigger spring action for the second type of Fan crossbow is performed when withdrawing the stick from the split, the trigger spring of the hand and fingers becoming taut and the fingers curving more as the stick is gripped.

It should be noticed that the spring actions of the hands and fingers and those of the mechanical springs formed by the splits occur at the same time; the spring action of the hand and fingers and that of the split, when the first type of crossbow is being used, occurring simultaneously; and the spring action of the hand and fingers in withdrawing the stick and the spring actions of the splits, when the second type of crossbow is being used, similarly occurring simultaneously. Furthermore, it can be seen that, when setting the mechanical springs, the mechanical spring devices and the human spring setting devices work at the same time.

When the stick has been put in the split, the human trigger spring action has already been partly used to open the split, or, in other words, to set the trigger spring. When any mechanical device is used, primarily it must be set or worked by its corresponding human device. The mechanical device does not replace the human one, but merely performs later and more conveniently the actions the human one has already partly performed. Primarily the human device must be used, then the mechanical device can continue the work of the human device. This principle holds good for all mechanical parts of a rifle or shot gun. For example, the shot gun has a mechanical trigger spring; but it must be set by human actions, and it is set by opening the breech and closing it. Similarly, the rifle's trigger spring is set by pulling back the bolt and then pushing it forward; but pulling back the bolt and pushing it forward are performed by human actions. Behind the actions of each part or device of a rifle or shot gun which has been studied, are the actions of its corresponding human offensive device. The barrel of a rifle guides the bullet, but the bed of the barrel is formed by the hand and fingers in which the barrel lies, and the human part of the barrel really guides the bullet. The trigger, when pulled, sets free the power to propel the bullet, but it must be pulled by

the finger. The trigger spring moves the trigger, but the spring is set by the rifleman pulling back and pushing forward the bolt. Offensive devices like flesh grooves, human triggers, and human trigger springs, may be said to be primary or original offensive devices, and their mechanical counterparts like barrels, metal triggers, and metal trigger springs, secondary or derived offensive devices, the secondary devices always deriving their powers from the primary ones, and performing similar actions to those performed by the primary ones.

The strings of the mediaeval crossbow provided with a revolving nut and long lever are set free by squeezing the long lever up against the lower part of the stock. Inside the stock is a small metal spring, which presses on the top of the lever and prevents it being accidentally jolted out of engagement with the notch in the nut. The lock is reset simply by turning the nut until it re-engages the end of the lever. The squeezing action is performed against the slight pressure of the metal spring. The use of the metal spring allows the fingers to squeeze slightly on the lever just before shooting, and steadies the action of the human trigger spring.

The Malabar crossbow's lock has no mechanical spring, and the trigger spring is formed wholly by the muscles of the hand and fingers pulling the trigger.

As the lock of the bullet-shooting crossbow is being set, the metal spring, which was tightened by the nearer approach of the sears P and S, becomes less taut. When the finger presses the trigger or the button, this spring suddenly becomes compressed and taut, and its action is similar to that of the metal spring of the crossbow provided with a revolving nut and long lever, but opposite to that of the spring formed by the hand and fingers when releasing the strings of a bow.

CHAPTER 36

THE BARREL AND BREECH (CROSSBOW)

IT has been explained that the barrel for the arrow of the bow and arrow machine is in two main parts, one part being formed by the groove made in the left hand by the foreshaft of the arrow, and the other part by the grooves made in the right hand fingers by its butt. The human parts of the barrel do not meet, except perhaps sometimes when the hands are together just before the bow is drawn. The fore part of the barrel, it has also been explained, is sometimes partly mechanized by means of a horn, iron, or wooden groove held in the hand that holds the bow handle.

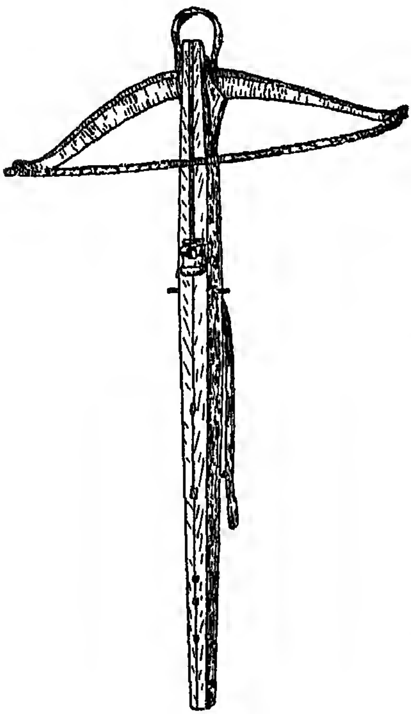


FIG. 54.
CROSSBOW, WITH GROOVE FOR QUARREL, XVIIth Cent.
Wallace Collection
(From a photograph)

The barrel for the arrow of the early crossbow was probably formed by a groove cut in the top of the stock, and, of course, also by the left hand of the crossbowman supporting the fore part of the wooden stock and groove and arrow.

The barrel of the early crossbow machine therefore was formed in much the same way as the barrel of the bow and arrow machine when an arrow runs in a wooden groove held by the left hand. The missile in many modern types of crossbow machines similarly rests merely in a groove cut in the top of the stock. The arrow of the Fan crossbow, for example, rests in a very slight groove in the top of the stock. The arrow of the Chinese repeating crossbow also rests in a groove in the top of its stock.

The complete barrel of the crossbow is therefore in two main parts. A mechanical part is formed by the fore part of the stock with the groove cut in it, and a human part by the left hand of the crossbowman. A bed is made in the hand and fingers which conforms to the shape of the stock, and automatically a good fit of the human and mechanical parts of the barrel is obtained.

By studying weapons with reference to the machinery of the body which wields them it can thus easily be seen that the barrel of the crossbow or gun has been developed from the human barrel of the bow and arrow machine, and that it is related to the barrels of all other types of offensive machines. If weapons are regarded as objects complete in themselves and are studied without reference to their complementary parts formed by the body, it is not evident that the arrow of the archer has a barrel and breech in which it rests and from which it is shot; and the barrel of the crossbow or gun appears to be an "invention". Indeed if the counterparts of weapons formed by the body are not noticed and studied, the study of weapons degenerates into a vain search for "missing links" between different types of weapons, and most types of weapons have to be regarded as having been invented. However, as is shown in this work, there is no need to be reduced to the expedient of accounting for the origin of any type of weapon by saying it has been "invented".

Many crossbows combine features of the Turkish archer's horn groove or Egyptian archer's metal groove and the Siamese archer's wooden groove, the mechanical part of the

barrel consisting of a horn or metal groove sunk in a wooden groove in the top of the stock. The complete barrel is then in three main parts. One part is formed by the horn or metal groove, another by the wooden stock in which the horn or metal groove lies, and the other by the contrivance formed by the left hand. As the left hand grasps the stock, the stock makes a bed in the skin and flesh of the fingers in which to lie. If the three parts of the barrel could be separated without the hand losing its form, it could be seen that the three parts fitted into each other, and that the barrel of a crossbow thus consists of mechanical and human parts.

It is the human part of the barrel that really holds and guides the quarrel. The mechanical parts of course can take no actions unless they are moved and operated and controlled by the hand.

It is difficult to provide a crossbow with a barrel of circular section, because the strings must slide along the top of the stock. An attempt to overcome this difficulty can be seen in the barrel provided for the slurbow, which is slit to allow the strings to slide along. The maker of the Ba-kwiri crossbow has provided a barrel of circular section for the whole of its length, but the barrel is placed beyond the reach

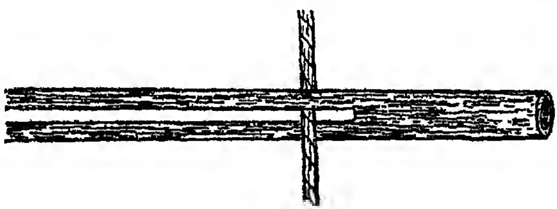


FIG. 55. DIAGRAM OF SLURBOW BARREL

of the bow strings. The barrel of the Chinese repeating crossbow is fully formed at the muzzle, where the clasps hold the box or magazine to the stock.

However well polished the barrel of a crossbow may be, a certain amount of friction is generated between the quarrel and barrel as the quarrel is shot. There is of course very little friction between the arrow and the human groove of the archer. Makers of crossbows tried in many ways to lessen

the friction between the missile and its barrel. One method was to make the quarrel of greater girth at one place, say at its middle, than elsewhere, so that it rested only at one point on the barrel. Another method was to revert more to the archer's type of foreshaft barrel, and allow the quarrel to be supported only at one place by a small ivory cross piece fastened to the top of the fore part of the stock. The quarrel was then shot along or just over this ivory device in much the same way as the archer's arrow was shot over the flesh groove in the left hand. The ivory support is clearly a modified and mechanical reproduction of the flesh groove, and reproduces many of its features.

The back part of the crossbow's barrel is formed often merely by continuing the fore part as far as the place to which the strings are drawn. But in many crossbow machines the back part is formed by mechanical fingers which copy fairly closely certain devices formed by an archer's right hand fingers as he grips the butt of the arrow. The mechanical fingers are provided by the fingers of the revolving nut, or barrel as it is often called.

The fact that crossbowmen call the revolving nut a "barrel" is of much interest and considerable importance, for it helps to confirm the belief that the nut forms the barrel, or part of it. Often the name given to a part of a weapon reveals much about the functions of the part, and very often reveals the human prototype of the part. Thus, crossbowmen call the ends of bow nocks the "thumbs", and as has been explained they are indeed mechanical counterparts of the devices formed by thumbs holding string ends. Gunsmiths call the fore part of the butt the toe, and its back part the heel, and the human prototypes of these parts are thus clearly indicated. Names given to parts of crossbows and guns, like the stock, butt, butt end, and heel-plate, easily reveal the human prototypes of these parts. Probably the resemblances of parts of weapons to parts of the body and similarities of methods of working of mechanical and human parts have caused wielders of weapons to give them names corresponding to names of parts of the body. The theory

that parts of weapons are related to parts of the body is therefore probably as old as the making of weapons; and it is curious that this similarity of names of mechanical and human parts has been overlooked by students of weapons and its significance never studied.

It can therefore safely be assumed that the nut forms the barrel or part of it, and a little study soon shows that this is so.

The fingers of the nut point upwards, and the butt of the quarrel or bolt is pressed between them. The mechanical fingers of the nut then grip the butt, somewhat after the manner in which an archer's fingers grip the butt of an arrow; and the nut besides forming a catch to hold and release the strings forms a gripping device which successfully copies that of the archer, *Figure 51.*

That the fingers of the nut are mechanical reproductions of the crossbowman's finger devices can be understood by comparing the actions of the crossbowman's fingers with those of the fingers of the nut. To place the quarrel in position, the crossbowman grips its butt with his fingers. As he presses it between the fingers of the nut, the mechanical fingers grip the butt, and release the human fingers from the need for gripping it. The mechanical fingers also release the crossbowman's fingers from the need for directly holding and releasing the strings and butt.

There can be no great difference between the gripping device formed by the fingers of the nut and the gripping device formed by the crossbowman's fingers; otherwise the mechanical fingers could not smoothly and easily take over the work of gripping the butt as the crossbowman presses it into the nut.

The butt of an arrow impresses its shape on the archer's right hand fingers; but the opposite effect is produced in the crossbow machine when the butt of the quarrel is tapered to fit the fingers of the nut. As the crossbowman holds the butt to press it into the fingers of the nut, it impresses its shape on his fingers. But the fingers of the nut, conversely, may be said to impress their shapes on the tapered butt, the tapering being transferred from the mechanical fingers to the butt.

A harpoon shot from a crossbow is sometimes tapered at the butt, so that it can conveniently fit the nut, and be held by it. The butt of the Malabar crossbow's harpoon, for example, is tapered in this way, *Figure 43.*

The back part of the barrel of the Belgian crossbow is formed by its metal fingers, which form a two-finger type of catch for the strings. The metal fingers as they hold the butt press against it and the parts in contact with the butt form the back part of the barrel.

The crossbowman places the butt of his bolt between the fingers of the nut by pressing on the butt with a finger. There is a tendency for the butt to rise from between the fingers of the nut, and to prevent this, on some crossbows a small whalebone spring is fastened to the stock and is bent over to press on the butt, *Figure 39.* The whalebone spring is clearly a crude mechanical copy of the human device formed by the crossbowman's finger as he presses the butt into the nut. The whalebone spring, when one is fitted, helps to form the back part of the barrel. It presses on the top of the butt of the bolt; and the mechanical barrel is then formed on the top by the spring, on the sides by the fingers of the nut, and underneath by the semi-circular sectioned groove or barrel; but the mechanical parts do not join up to form a complete cylinder to enclose the butt.

The breech of the crossbow machine when the missile is of the arrow type is often not mechanized at all, or very little mechanized, and is formed usually simply by the crossbowman's right hand as he holds the small of the stock. His palm and parts of the fingers near it surround this part of the stock and form a kind of pouch, or breech, little different in form from the pouch made by an archer's right hand. As the human breech is not in contact with the butt of the missile, difficulties are often experienced in controlling the missile; and in many types of crossbows if the weapon is pointed downwards the missile will fall from the barrel and leave the strings.

The arrow of the Fan crossbow will fall off the stock if the weapon is jerked or pointed downwards, for the barrel

is merely a slight scratch in the top of the stock and there is no mechanical breech. Indeed it is so light and small that it may be blown off. The Fan crossbowman, however, prevents it falling from the barrel, by placing a spot of gum on the top of the stock. This makes the arrow and stock fit, or correspond, very closely because the arrow presses into the gum which then partly surrounds it, and close correspondence of arrow and top of the stock is thus easily ensured. The mechanical part of the barrel is then formed by the stock, the groove, and the gum.

A type of slurbow shoots a spherical ball through a barrel which is cylindrical at its fore part,[1] but the ball is liable to leave the strings and roll down the barrel if the weapon is pointed downwards. The ball of the early hand gun similarly was liable to roll down the barrel when the weapon was pointed downwards.

Mechanical parts of the back of the barrel and of the breech are formed by the leather pouch of a prodd or bullet-shooting crossbow. The sides of the pouch form the barrel and the back of the pouch forms the breech, much as in the pellet bow machine; but their human counterparts are not in contact with them, the fingers being placed round the small of the butt, having been transferred away from their mechanical counterparts perhaps along devices of the lock.

A forepart of the barrel of the prodd is formed by the left hand, and by the part of the stock held by the left hand; but there is no groove in the stock for the bullet to be shot along. But mechanical fore parts of the barrel are formed by the sides of the pouch when they are forward. The sides of the pouch, at the beginning of the drawing of the strings are forward, and then form mechanical parts of the fore part of the barrel. They cease to form parts of the fore part of the barrel when the strings are fully drawn, and then form mechanical parts of the back part of the barrel. They again form parts of the fore part of the barrel as they go forward with the missile after release. It will be remembered that

[1] Sir Ralph Payne-Gallwey, Bt., *The Crossbow*.
A. Demmin, *Arms and Armour*.

the fore part of the barrel of the fist machine is somewhat similarly formed by a fist which at other times forms the back part of the barrel.

The barrel of the rifle is continuously formed for the whole of its length. It is slightly more developed mechanically than the barrel of a crossbow, for instead of a barrel of semi-circular section, it has one of circular section, which completely surrounds the bullet as it travels along the barrel. The fore part of the barrel of the rifle machine consists of two main parts. A mechanical part is formed by the metal barrel and the wooden stock in which it lies, and a human part is formed by the left hand fingers in which the metal barrel and stock fit. The metal barrel fits into the top of the stock which is grooved to receive it, and the wooden stock fits into the hand which automatically conforms to the shape of the parts of the stock with which it is in contact.

If the wooden stock of a rifle or shot gun or other hand gun does not extend to the place where the weapon is held by the left hand, the fore part of the barrel is formed only by the metal barrel and the left hand in which it lies; and the ball or bullet is shot or the pellets are propelled over the left hand at a distance above it depending on the thickness of the metal of the barrel, which may be only a few hundredths of an inch. The wielder of a shot gun, rifle, or other hand gun, then shoots almost immediately over his left hand as the archer always has done; and centuries of developments of weapons, which included a change over from shooting with the power of bow arms to shooting with the power of gunpowder or other explosive, have not altered the way the missile is shot just over the left hand.

The length of the crossbow's barrel when the crossbow shoots an arrow type of missile is the distance between the muzzle, or fore end, of the mechanical barrel and the beginning of the breech. The groove or metal barrel projects beyond the left hand, and gives the human barrel, which is formed by the hands, a mechanical extension in length. The length of the barrel does not change after the strings have been drawn.

The length of the barrel, however, changes during the drawing of the strings. When the strings are drawn by both hands with the feet placed on the bow, the back part of the barrel is formed by the hands, and the fore part by the feet; and the length of the barrel varies during the drawing of the strings from its minimum to its maximum length.

As the strings are drawn by a goat's foot lever or other mechanical apparatus, the distance between the muzzle and the right hand varies; and the length of the barrel therefore varies.

The distance of the right hand from the left, or from the handle of the bow, of a prodd changes as the lever is being pressed down to draw the pouch back; and therefore the prodd has an extensible barrel.

It is difficult to discover if the hand gun machine has an extensible barrel. The length of the barrel is constant after the wielder's hands have been placed in position on the weapon; but a study of other machines shows it is necessary to see if any variations occur in the length of the barrel during the generating of the power before deciding whether or not the machine has an extensible barrel. If the hands of a wielder or other person who generated the power move relatively to each other or to the mechanical barrel of the weapon, the machine clearly has an extensible barrel. Since the hands of the early makers of gunpowder did move relatively to each other as they mixed the gunpowder, it is probable that the hand gun has an extensible barrel.

The length of the barrel of the great gun machine can be seen to vary during the wielding of the weapon. When the weapon is fired, the barrel moves backwards, and is immediately afterwards pushed forwards by powerful buffers or springs or other contrivances; and during this movement, the distances between the muzzle of the barrel and the hands of the gunners obviously varies. The great gun machine therefore has an extensible barrel.

The diameter of the barrel of the offensive machine is seldom constant along its length. The barrel of an archer, for example, is usually of smaller diameter, or bore, at one

end than the other, because the arrow is seldom a true cylinder and tapers from one end to the other, often irregularly. If the butt is of larger girth than the foreshaft, the bore of the back part of the barrel is larger than the bore of the front part; and conversely if the butt is of smaller girth than the fore part, the bore of the back part of the barrel is smaller than the bore of the front part. When the foreshaft and shaft are made separately, the back part of the barrel is usually of a different bore from that of the front part. The peculiarities in the bores of different parts of the barrel of the bow and arrow machine are closely copied, as might be expected, in the bores of crossbow and gun machines.

The diameter of the middle portion of the strings of a crossbow is usually about half an inch, and the diameter of the butt of the bolt is also usually about half an inch to correspond. The bolt tapers slightly towards the front to an increased diameter of about five-eights of an inch.[2] Although the bolt increases in diameter from its butt to its head, the groove in which it is placed does not taper similarly. But if the bolt is supported at its fore part by an ivory cross piece, the diameter of the curve of the cross piece must correspond fairly closely to the diameter of the part of the bolt supported, and therefore the bore of the front part of the barrel will be different from that of its back part.

The interior of a hand gun barrel is not usually a true cylinder, and the bore varies along its length sometimes irregularly. In the days of the flint lock gun, sometimes the barrels were made "tight behind", that is with the bore smaller near the breech, or "open behind", that is with the bore greater near the breech.[3] The middle portion was usually a true cylinder, and the fore part tapered with the diameter increasing as the muzzle was approached. Later it became customary to make barrels as true cylinders, but this practice was soon abandoned as unsatisfactory; and then the fore half of the barrel was made a true cylinder of a

[2] Sir Ralph Payne-Gallwey, Bt., *The Crossbow.*

[3] Major Sir Gerald Burrard, Bt., D.S.O., R.F.A., *The Modern Shotgun.*

certain diameter and the back half a true cylinder of a slightly smaller diameter, the two halves being joined by a taper or cone. This type of barrel resembles the type used by an archer when the foreshaft is made of one diameter and the shaft of a different diameter. The barrel of the modern shot gun is seldom a true cylinder. Also often one of its barrels is constricted at the muzzle, the constriction being called the choke. The barrels of most modern military rifles taper towards the muzzle, either evenly or in steps.[4] The barrels of hand guns thus copy many of the barrels of the bow and arrow or crossbow.

When feathered, crossbow bolts usually have three feathers, but those used in war two feathers. The feathering device sometimes takes the form of three flanges or grooves along the length of the bolt, and, according to Sir Ralph Payne-Gallwey, the purpose of the grooves is "to take the place of feathers"; and relationships between the feathering device of an arrow or bolt and the rifling on a gun barrel become evident, for the grooves in a crossbow's bolt are types of rifling, although not made spirally. According to McHardy, "probably rifling evolved from the early observation of the action of the feathers on an arrow and from the practical experience of cutting channels in a musket, originally to reduce fouling, being found beneficial to the weapon's accuracy." [5]

The interiors of some crossbow barrels are said to be rifled,[6] but the ordinary crossbow with a half barrel has no rifling on the surface of the barrel. Some sporting shot guns are slightly rifled near their muzzles. The modern rifle, of course, as the name shows, has a rifled barrel.

Mechanization allows the number of grooves on the interiors of barrels to be distorted, and gun barrels may have as few as two or as many as twelve grooves. Straight grooving was applied to fire arms as early at 1480, and grooves without twists were made in musket barrels in the 16th

[4] *Encyclopaedia Britannica*, Article Small Arms.
[5] *Encyclopaedia Britannica*, Article Ordnance.
[6] H Ommundsen and E. H. Robinson, *Rifles and Ammunition, and Rifle Shooting;* W. W. Greener, *The Gun and its Development.*

century. The rate of spiralling varies in different types of rifles; and is not always constant in a barrel, but may increase or decrease along the length of the barrel. The Baker rifle, of about 1800, had seven grooves which made a quarter of a turn along its 30 inch barrel, or one turn in 120 inches. The Minié rifle of about 1850, had four grooves which made one turn in 72 inches. The Lee-Enfield rifle of the British army has five grooves which make one turn in 10 inches.

CHAPTER 37

THE MAGAZINE

THE magazine of the fist machine is not mechanized, but the machine can deliver blows in rapid succession, and there is no danger of "running short of ammunition." Blows cannot be repeated in such quick succession when the fist is mechanized say by means of a caestus or club, because the weight of the mechanical parts and in the case of the club machine the need for exerting leverage on the mechanical parts tends to prevent quick repetition of a blow. The number of blows a slinger can deliver in succession depends on the capacity of his bag, and when the stones have all been slung, he must refill it before he can deliver more blows. In an American Indian archery game, the contest is to see who can discharge arrows in quickest succession, and as many as ten arrows may be in the air before the first has hit the ground.[1] The magazine of the Chinese repeating crossbow can hold twenty arrows, and it is said ten shots can be fired from it in fifteen seconds. Another type of Chinese crossbow shoots two arrows each time the lever is worked, and the rate of shooting may be twenty arrows in fifteen seconds, or double the rate obtainable with the other type of crossbow. No other type of crossbow is provided with so highly mechanized a repeating action. The U.S.A. army rifle, model 17, whose magazine holds five rounds, it is said has fired thirty well aimed shots in one minute. Mechanization of the offensive machinery by means of a machine gun allows a quickening of the rate of delivery of blows, but causes the disadvantage that the machine soon runs out of ammunition. The rate of fire of a cannon or great gun is poor, and usually a considerable interval of time must elapse before a blow from it can be repeated.

[1] G. Catlin, *Manners, Customs, and Condition of the North American Indians.*

When an archer carries a leather or a metal quiver, he does not directly hold the spare arrows, and the work of holding them is directly performed by the mechanical contrivance of the quiver. The quiver is held by the archer, strapped or fastened to his belt, or attached to his body in some other way. Indirectly and primarily therefore the archer holds the spare arrows; and when a mechanical quiver is used, the quiver contrivance is formed partly by the mechanical quiver and partly by the body which supports it.

Only the actions of holding the spare arrows are performed by mechanical means, and the arrows must be placed in the quiver by human actions, and be selected and taken out and be fitted to the strings by human actions; and the fingers and hands and other parts of the body of the archer must form devices for these purposes. When a quiver is fitted, very few of the repeating actions are therefore mechanized.

When a Chinese repeating crossbow is used, the actions of selecting the arrows from the quiver, or magazine, and fitting them successively to the strings are directly performed by mechanical means. As soon as an arrow is shot, the one which had been next above it in the box, or magazine, falls to the bottom of the box, which forms the top of the stock, and is then ready to receive the strings. As the lever is worked, it pushes the box forward until the strings drop into the catch on the stock behind the arrow. As the lever comes back, the strings tighten until the box closes down on the bottom limb of the stock and the peg is driven up to push out the strings to shoot the arrow. The lever is worked to and fro continuously until the last arrow has been shot.[2] The actions of placing the arrows in the box are performed by human means, and are not mechanized; and the Chinese crossbowman, like the European rifleman, must place the missiles in the magazine himself.

[2] Sir Ralph Payne-Gallwey, Bt., *The Crossbow;*
The Rev. J. G. Wood, M.A., F.L.S., etc., *The Natural History of Man;*
Colonel C. L. Spencer, *Glasgow and West of Scotland Society,* 17th Jan. 1907.

The shot gun has no magazine, but repeating actions are obtainable for two shots in succession by the device of placing two barrels side by side from which shots can be fired in succession; but a double-barrelled gun is really two guns placed side by side. Several barrels, which can be used in succession, are fitted to the revolver, the fore part of one barrel acting as the fore part of all the back parts of the other barrels in turn as the barrels revolve. The rifle nowadays usually has a magazine, which may contain up to about ten cartridges, which are fed into the breech on the same principle as the arrows are fed into the breech and barrel of the Chinese crossbow. The Chinese crossbowman works the lever to and fro to feed the arrows to the barrel; the rifleman works the bolt to and fro to feed the cartridges to the barrel. The action of placing the cartridge in the breech is directly performed by the mechanical device of the bolt of the rifle, but indirectly and primarily by the rifleman, who must pull back and push forward the bolt each time he wishes to shoot.

The magazine cover of the rifle is at the inside of the bend of the stock, where the stock and butt meet, and from its position corresponds to the scrotum of the wielder. Like the human scrotum it projects from the inside of the bend. It is about the size of the scrotum; and is evidently a crude mechanical reproduction or embryo of it. It is made of metal, and does not correspond closely in materials to the materials of its human counterpart which are of skin. The bullets are held in the magazine cover, and are ejected in succession through the tube or barrel which evidently corresponds to and is a mechanical counterpart and extension of the penis erectus.

The magazine cover, or box, of the Chinese repeating crossbow, *nou koung*, is on top of the stock, *Figure 47*, and is transferred from a position below to one above the stock compared with that of the rifle (Rule 8). It is much larger than the magazine cover of the rifle, and is a very distorted and magnified extension of the wielder's scrotum. But the weapon is sometimes wielded by two persons, and it may therefore perhaps be extensions of the scrotums of the

wielders combined into a single contrivance. If this is so, it is not a very distorted extension. The magazine of the crossbow and rifle are both filled from above.

The missiles of the Chinese crossbow are small arrows, sometimes very slightly feathered. They probably correspond to the human sperms or seeds, as is fairly evident from the fact that they are contained in the mechanical scrotum and are ejected through the barrel (Rule 4). Rifle bullets therefore also must correspond to sperms. Some features and actions of the human reproductive organs are reproduced more closely by machine guns and shot guns than by the rifle, for the machine gun ejects its missiles in a stream or in bursts from the magazine through the barrel. When a shot gun is used, numbers of small shots, or seeds, are ejected from the barrel.

Close relationships between the natures of arrows and seeds are proclaimed in the well known egg and dart ornamentation which was often a prominent feature of ancient architecture and is one which modern builders are fond of using. Cupid or Eros with his bow similarly proclaims that the dart of love and the arrow of death are the same instrument. According to Rule 11, actions can be exactly reversed, and so there need be no difficulty in understanding that the death dealing arrow or bullet corresponds to the life giving sperm or seed. A bullet is a modified type of arrow, as can be seen by tracing the development of the bullet or shell from the missile of the early cannon, which it has been explained was usually a padded arrow. Gradually the shape of the missile was changed into the form of a bullet or shell. But "for some years, bolts like crossbow bolts, called musquet-arrows, but without feathers, were fired frequently from hand guns, both on land and sea."[3] Some crossbows, it can be remembered, shoot bullets and others arrows.

Having discovered that the magazine case corresponds to the scrotum, it cannot now fail to be noticed that the archer's quiver or slinger's bag is often carried or worn in a position which reveals its derivation from the scrotum. Thus the

[3] Sir Ralph Payne-Gallwey, Bt., *The Crossbow*.

archer in *Figure 35* carries his quiver behind him, so that it is opposite his scrotum, the quiver being transferred from the front to the back of his body (Rule 8). The slinger in a figure on the Column of Trajan holds spare missiles in the folds of his dress, and the part of the dress which holds the missiles when allowed to hang down would apparently cover the scrotum, *Figure 31*.

The Scottish Highlander's sporran is a type of quiver. According to the dictionary the sporran is "a pouch usually covered with fur, etc., worn by Highlanders in front of the kilt." Some reasons for its use and form and materials and position are obvious. By wearing the typical feminine garment of a skirt or petticoat the Highlander feels he has laid himself open to the imputation of being a woman. To proclaim to others, and perhaps to reassure himself, that he has not lost his masculinity, he gives his scrotum and certain other parts associated with it artificial extensions and transfers them from the inside to the outside of the kilt (Rule 8). The sporran reproduces several of the features of the male reproductive organs. A discussion of sporrans, girdles, and similar devices, however, belongs more particularly to the study of clothes than weapons.

Neither the box of the Chinese crossbow nor the magazine cover of the rifle reproduces the materials of the human scrotum with any fidelity, and correspondence of mechanical and human materials is remote. But the archer's quiver reproduces the materials of the scrotum fairly closely when, as is usual, it is made of skin or leather. The archer's quiver is always much larger than the human scrotum, and is greatly distorted in size.

* The slinger's bag sometimes corresponds fairly closely in

* Some support for the belief that the slinger's bag is a mechanical form of the scrotum is perhaps given by noticing some similarities of ancient names for the bag and scrotum. The Greek word for the slinger's bag was πηρα which is nearly the same as πηριν which was the name for the scrotum or bag of the testicles. The ancient Romans called the slinger's bag the *marsupium;* and the English word marsupial, which describes animals like the kangaroo and opossum which carry their young in a pouch, has been derived from the Latin word. The word bag or pouch is also used in English to describe both the mechanical and human contrivances.

shape to the scrotum; and with its stones reproduces both the scrotum and the testes. But when more or less than two stones are contained in it, correspondence of the number of mechanical testes to the number of human testes is remote.

Features of the testis and scrotum are reproduced in the prodd, the pellet bow, the sling, and the bolas.

It was explained earlier that certain mechanical counterparts of human parts are thrown by some machines which are retained by others. Thus, when the shot putter or stone thrower is in action, mechanical counterparts of the fist are thrown; but when a club is thrown mechanical counterparts of the wielding arm and fist or wielding arms and fists are thrown. When the slinger is in action mechanical counterparts of the fist are thrown, but mechanical counterparts of the strings of the arm are retained. When the hammer thrower is in action, however, mechanical counterparts of the strings and fists are thrown.

Somewhat similarly, mechanical counterparts of the seeds are thrown by some machines, but by others mechanical counterparts of the testis or of the testis and scrotum are thrown. Thus, the prodd or bullet-shooting crossbow throws mechanical counterparts of the testis but retains the mechanical counterpart of the scrotum, that is it throws the ball or bullet but retains the bag or pouch. The pellet bow and sling similarly throw a mechanical counterpart of the testis but retain the mechanical counterpart of the scrotum. The wielder of a bolas, however, throws mechanical counterparts of the testis and scrotum together, for the ball and its outer covering of skin or leather are thrown together.

The bolas consists of one, two, three, or more balls covered with leather or skin and connected by cords of thong or leather or hide. One type, the somai, has two balls only. Another, the achico, has two balls connected to a third ball by a longer cord than that which connects the other two balls. The bola perdida has only one ball. The Eskimo has a bolas type of sling for bringing down small birds in flight, which has seven or eight strings and balls. The ball of the South American two-ball or three-ball bolas is usually about

the size of a cricket ball, but may be as large as a turnip. The Eskimo balls are small and acorn shaped. A boy's conker is a one-ball type of bolas.[4] A conker is the seed of the horse chestnut and is covered by a natural skin. Since the ball of the conker is a seed and its outer cover is of skin, and since a conker is a one-ball type of bolas, it is fairly evident any bolas ball corresponds to a seed and its covering to the skin covering the seed. The ball of the bolas therefore corresponds to the testis and the covering to the scrotum, as is also evident from some similarities of shapes, especially in the case of the Eskimo balls, and from the fairly close correspondence of materials of the scrotum and bolas coverings, for like the testis the ball of the bolas is enclosed in a covering of skin or leather, or by a natural skin as in the case of the conker. When a bolas is thrown, as was stated above, counterparts of the testis and scrotum are thrown together, since the ball and the skin or cover of the ball are thrown together.

The missile of the prodd is not ejected through a barrel or tube after the manner of the arrow or bullet, for the container for the missile is in the form of a pouch. This pouch corresponds to the scrotum and the bullet corresponds to the testis. The bullet is distorted to a smaller size than the testis. The ball of the bolas conversely is usually distorted to a much larger size than the testis. The pouch of the prodd is also smaller than the scrotum and is similarly distorted to a somewhat smaller size. The missile is contained in the mechanical scrotum in a manner somewhat resembling that in which the testis is contained in the scrotum. The missile of the prodd does not closely resemble the testis in shape, for the bullet is spherical and not oval. The missile of the slinger, however, is usually oval, and may resemble the testis not only in shape but also in size. The ancient Greek sling stone was oval, and about the size of the testis. The sling stone of the modern New Caledonian slinger is oval; that of the Sandwich Islanders is also oval. It will be remembered that the ancient Romans called their sling stones glandes

[4] The Rev. P. H. Francis, M.A., *A Study of Targets in Games.*

from their resemblances to acorns, which of course are the seeds of the oak tree. The slinger throws the mechanical counterpart of his testis, but retains the mechanical counterpart of his scrotum which is fastened to the strings of the sling.

In previous chapters it was shown that the barrel has been developed from barrel devices formed by the hands; the pouch, or breech, from the cup device formed by the hand to contain and direct a stone or other missile; and that the stone is a mechanical reproduction of the fist or parts of it. It thus becomes apparent that when human offensive devices are mechanized human reproductive devices are mechanized at the same time. When, for example, a crossbow or hand gun is placed upright with its butt end on the ground, the outline of the reproductive machinery as well as the outline of the offensive machinery can be seen. When studying the offensive machinery a study is automatically made at the same time of the reproductive machinery, and a knowledge of one machine gives knowledge of the other. When mechanizing the offensive machinery automatically the reproductive machinery is mechanized. Mechanical development of the offensive machinery and of the reproductive machinery must therefore be simultaneous, and neither can be developed or extended without a corresponding development and extension of the other occurring.

Chapter 38

THE SIGHTS

IT is difficult, and probably impossible, by direct observation to discover how the wielder of the fist, claws, foot, head,* body, or other human weapon, aims his blow or thrust. But some facts about the human sighting devices can be known after a study of the mechanical sights of bows, crossbows, shot guns, rifles, and other weapons.

Some modern bows are fitted with mechanical sights; but archers usually will not allow them to be used in competitions. The sights of the ordinary bow and arrow machine are slightly mechanized when the barb or point of the arrow is used as the foresight, because the barb or point is a mechanical and not a human device. According to Walrond, "in shooting with a bow the point of the arrow resting on the left hand takes the place of the foresight on a rifle, the distance between the eye and the forefinger of the right hand answering to the back sight."[1] Since the point or barb of an arrow, as has been explained, is a mechanical reproduction of the forefinger or of a knuckle, the human prototypes of the sights, it seems, are the sighting devices formed by the fingers or knuckles. Probably therefore the sights of the wielder of the fists are formed by a knuckle of the left hand and a corresponding knuckle of the right hand, and the blow or thrust from a fist is probably always directed along the line from the rear to the front knuckle.

*The use of the head as a weapon is described by R. H. Dana, in *Two Years Before the Mast*:— "The next little diversion was a battle on the forecastle, one afternoon, between the mate and the steward. They had been on bad terms the whole voyage, and had threatened a rupture several times. Once, on the coast, the mate had seized the steward, when the steward suddenly lowered his head and pitched it straight into Mr. Brown's stomach, butting him against the galley . . . " Another battle is also described, in which the steward again used his head as a weapon.

[1] Col. H. Walrond, *Archery for Beginners*.

The sights of the Andaman bow and arrow machine are partly mechanized by means of the blade of the arrow and barb and seam of the fastening. "In the ē.la- (pig-arrow), the blade is so fixed as to be in line with the seam of the fastening at the end of the shaft, and, whether provided with one or more barbs, these are always placed in a line with the blade, the seam above referred to being used as a 'sight'."[2]

Early crossbows had no mechanical sights, and aim was taken in a rough and ready way by pointing the crossbow as nearly as possible in the direction of the target. The front sight of some crossbows is formed by the barb of the quarrel as it rests on the stock; and the rear sight by the top of the joint of the right thumb as it rests on the stock, the right hand being placed round the small of the butt. No part of the offensive machine can be fully mechanized, and therefore the barb of the quarrel cannot be the complete front sight. This is formed by the barb and by the left hand, which supports the barb and gives it the required elevation.

On some crossbows a strip of wood of the width of the stock is fastened to the top of the stock, at the place where it is held by the right hand. A few grooves of different depths are cut in this strip of wood, in one or other of which, at the discretion of the wielder, the thumb is placed. To aim the crossbow, a sight is taken over the top of the knuckle of the thumb to the barb of the quarrel used as a foresight. Placing the thumb in one groove gives one elevation, and in another a different elevation.

When a sight is taken over the knuckle of the thumb, the back sight is not formed entirely by the knuckle. Complementary parts are formed by the groove in which the thumb rests, by the strip of wood, and by the hand which supports the stock.

The right thumb, placed on the top of the stock and used as a back sight, is replaced by mechanical devices on some crossbows. When a whalebone spring presses on the butt of a quarrel sometimes a V-shaped groove is cut in its top parallel

[2] E. H. Man, *On the Aboriginal Inhabitants of the Andaman Islands.*

to the axis of the barrel so that the V can be used as a back sight.[3] This type of back sight is clearly related to the thumb or forefinger knuckle of the crossbowman, according as the thumb or forefinger presses the butt of the quarrel between the fingers of the revolving nut, for the whalebone spring, as has been explained, continues the action of the finger which pressed the butt into the nut, and takes the place of the finger.

A V-shaped cut is upside down compared with the knuckle of the thumb, whose shape resembles rather that of a wide Λ, or caret (Rule 11). A V-shaped notch is often used on the back sight of a rifle or other hand gun; and the human prototype of the back sight of a gun is therefore the device formed by the knuckle of the thumb.

The front and back sights are complementary devices, and some devices found on the front sights of some weapons are found on the back sights of other weapons, having been transferred during the process of development of the sights. For example, the back sight of a rifle often has a horizontal bar with a V-shaped notch cut in it, or a peep-hole in it, and the bar can be raised or lowered between two vertical uprights to vary the elevation. On a bullet-shooting crossbow, however, a similar type of device is found on the front sight, consisting of a bead on a horizontal thread, which can be moved up or down between two uprights On the bullet-shooting crossbow, the bead takes the place of the V-shaped notch on the bar of the rifle, or of the peep-hole in the bar. The elevation of the crossbow

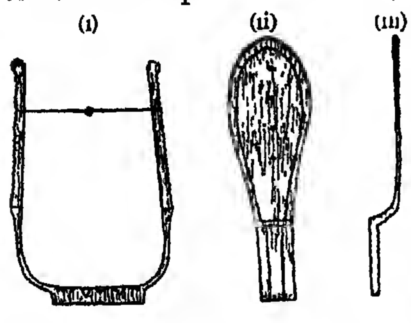


FIG. 56.
SIGHTS OF BULLET-SHOOTING CROSSBOW
(i) Front sight
(ii) Rear sight (front view)
(iii) Rear sight (side view)

[3] Sir Ralph Payne-Gallwey, Bt., *The Crossbow*.

can also be varied by using one or other of the three or four peep-holes in the back sight, at the discretion of the wielder.

The manner of sighting over the thumb, as it lay on top of the stock, was used by the hand gunner for many years; and the back sight of the hand gun machine, therefore, before it was mechanized, was formed by the knuckle of the thumb, which is evidently the human prototype of the modern mechanical backsight.

Although the sights of a rifle help the rifleman to obtain the correct elevation, they are incomplete without the human elevating devices formed by the body. The main parts of the elevating devices must still be supplied by the body of the rifleman; and the sights are useless unless the left hand and the right hand work with them to obtain the elevation. The use of mechanical sights allows the rifleman to aim directly at the object to be hit; but the left hand must be raised or lowered to allow this to be done. The rifleman looks across the sights at the object, after estimating its range and adjusting the sights accordingly, and the left hand must be raised or lowered the exact distance to allow this to be done. The sights of the rifle therefore consist of two main parts; a mechanical part formed by the sights, and a human part formed by the elevating devices of the hands.

Chapter 39

THE BLOW GUN

THERE are several varieties of blow guns. The main feature of the blow gun, or blow tube or blow pipe as it is sometimes called, is a tube through which a pellet or a short, slender dart or arrow is propelled by air from the wielder's lungs. The length of the tube varies. In some types it is as little as two feet long, in others may be nearly twenty feet long. Double barrelled and even triple barrelled weapons are sometimes used.[1] The boy's pea-shooter is a type of blow gun. Blow guns are used chiefly in South East Asia and tropical America.

The sumpitan of Borneo is about eight feet long. Its barrel, which is very accurately bored, is about half an inch in internal diameter. The sumpitan is a dual purpose weapon, and has a bayonet type of spear fastened to its fore end. The arrow is seven or eight inches long, and as slender as a steel knitting needle. It is padded at its butt with pith or soft wood so that it fits tightly into the barrel. The range of the weapon is not much more than about forty yards, but the arrow is poisoned. The quiver which is made of bamboo and holds thirty to forty arrows is stuck in the belt and carried at the side.

Some of the best types of blow guns are made in Guiana. One type, the zarabatana, is made in two pieces of semi-circular section which are bound together to form the barrel. The weapon is heavy. A lighter and very beautifully made instrument is the pucuna of the Macoushie tribe.[2]

The pucuna is about eleven feet long, and consists of a tube contained in another tube which supports the inner tube and keeps it straight. The bore of the barrel is small, and

[1] Horniman Museum Handbook, *War and The Chase.*
[2] C. Waterton, *Wanderings in South America;*
The Rev. J. G. Wood, M.A., F.L.S., etc., *The Natural History of Man.*

the arrow which is about ten inches long is padded with wild cotton to prevent windage, or loss of air during propulsion. The quiver is formed by stringing the arrows on two parallel cords and then rolling them into a bundle, the points being protected by a kind of wheel. As many as five hundred arrows may be carried in the quiver. The arrows are poisoned, and are sometimes feathered spirally with bark to make them spin in flight. Their range is about three hundred feet.

The barrel of the blow gun is similar in principle to the barrel of the gun or crossbow, for it consists similarly of a tube of circular section or of two halves of semi-circular section joined together. The pucuna is held with the left hand placed palm upwards, and the left elbow is placed against the hip. The right hand is placed palm downwards on the barrel, between the left hand and mouth piece. According to Wood, "this mode of holding the weapon is exactly similar in principle to that which is employed by the rifleman." The front sight of the pucuna is formed by an acuero seed, and its back sight by two teeth of the acouchi fastened in a lump of kurumanni wax.

The power to propel the arrow is obtained by expanding the chest, but the hands are not separated during this action. The power to propel the arrow from the ordinary bow, it will be remembered it was stated, is obtained similarly by expanding the chest, the hands being however separated during this action. Probably there is no fundamental difference between the way the power is generated for the blow gun and the way it is generated for the bow. Also probably there is no fundamental difference between the way power is generated for the blow gun and the way it is generated for the ordinary gun, for the wielder of the blow gun like the wielder of the ordinary gun propels his missile with a discharge of gas, air of course being a mixture of gases.

The barrel is connected to the mouth usually by a mouth piece, somewhat resembling the mouth piece of a trumpet or other similar type of musical instrument. The mouth piece is a mechanical extension of the device formed by the

wielder's mouth; and the mouth piece of the blow gun machine is formed by the human and mechanical devices together. Much skill and long training are required of the wielder so that he can form an effective mouth piece device which will combine with the artificial counterpart. The artificial counterpart, of course, is made in the way generations of experience have taught the makers is the best for fitting and combining with the human device.

It is evident the artificial mouth piece and the human device formed by the wielder's mouth together form a single contrivance. If they do not fit and combine, there will be an escape of air, or loss of efficiency in other ways, and they will not work together in harmony so that the air from the lungs or wind pipe will propel the missile as effectively as possible.

The barrel is connected to the lungs, and acts as a mechanical extension for the wind-pipe. Like most mechanical devices it is distorted in shape and is made straight, instead of curved as the wind-pipe devices are curved. Brass musical instruments like the trumpet, trombone, horn, and tuba, are curved and resemble more closely in shapes the human vocal organs of which they are mechanical counterparts and extensions. They are not made straight like a blow gun, for they do not propel a missile which must be aimed; and are not extensions of the offensive machinery of the body, but of the respiratory and vocal machinery. Their mouth pieces are therefore different from although somewhat resembling the mouth pieces of blow guns. Their tubes are not of uniform bore along their lengths, and magnification of the sounds made by the wielder is obtained by increasing the bore along the length of the tube and enlarging the end considerably. It should be unnecessary to point out that the musician makes the sounds, and that the instruments can make no music until fitted to and working in harmony with the lungs, wind-pipe, and other human respiratory and vocal devices.

The fact that the barrel of the blow gun is an extension of the wind-pipe devices reveals that the barrel of the gun is

also a mechanical reproduction of and closely related to these devices. This cannot easily be seen from a study of the gun machine. The missile of the blow gun is connected to the reproductive organs more directly, by way of the intestines, than is the missile of the ordinary bow or gun.

Since, as has been shown, the barrel of a gun is closely related to the human reproductive organs, and also to the respiratory organs, there is evidently a very close relationship between the human reproductive and respiratory organs; but the author has not advanced sufficiently in the study of weapons to know the exact relationship. No doubt some of his readers will be able to carry on the study and make this and many other discoveries.

Although it might seem, at first, that there is little in common between the blow gun machine and say the bow and arrow or hand gun machine, yet a little study soon makes it appear probable that there is no fundamental difference between them. A study of the blow gun machine will perhaps one day, when the study of weapons is more advanced, supply clues which will show the relationships between many devices and contrivances of the body which at present are not understood.

Chapter 40

CHEQUERING

THE small of the butt of a crossbow or hand gun, or place where the right hand makes its grip, sometimes has sets of lines, or chequering as it is called, cut lightly in the wood. A purpose of the chequering is to help the hand to obtain a good grip. The small of the butt of the nineteenth century bullet-shooting crossbow is chequered, *Figures 40, 43, 46*. The small of the butt of a shot gun is chequered, and the under side of the fore part of the stock which rests on the left hand is also chequered, *Figure 57*. The stock of the rifle is not chequered; and the hands must make their grips without the help of lines or markings on the stock. Chequering can easily be seen to be a crude mechanical reproduction of some of the sets of lines or markings of the hands and fingers, transferred from the hands and fingers to the parts of the stock with which they are in contact (Rule 7).

A multitude of markings, or lines, or creases, can be seen on the hands and fingers. In olden times the lines on the hands received much study; and Dr. G. M. Humphry remarks, "The lines upon the palm, or creases formed in closing the hand . . . were named with the names of the Planets and the signs of the Zodiac; and a science grew up akin to Astrology and Physiognomy. Cheiromancy was the name given to it; and numerous and voluminous treatises were written upon it. We are told that Homer was the author of a complete essay upon the lines of the hand . . . "[1] Some study has been given in recent years to the lines on the thumbs and fingers; and it is now known that they are differently formed for each person's hands, and that they do not change shapes or positions during a person's lifetime. A study of finger prints, as these lines are called, has become an essential part of a policeman's training; for any person can

[1] *The Human Foot and the Human Hand.*

be readily identified if copies of his finger prints have been made. A glance at the reader's own hands and fingers will show him that each part of the hand has its own distinctive types of markings.

Chequering on shot guns usually consists of a set of lines approximately parallel crossed by another set of lines

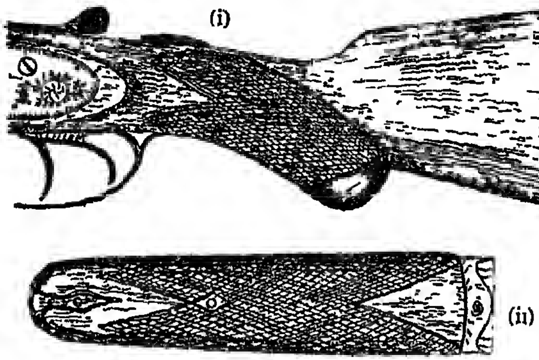


FIG. 57. CHEQUERING ON A SHOT GUN
(i) Small of butt
(ii) Fore part of stock

approximately parallel, the lines of one set crossing those of the other set so that small rhombuses or diamond shaped figures are formed. This type of chequering can be seen on parts of the hands, for example at the back of the fork of the thumb, on the ball of the thumb, back of the hand, back of the fingers, and elsewhere; and some of these human chequerings are close to the mechanical chequerings on the shot gun when the hands make their grips.

Presumably, ideally the markings on a weapon should correspond exactly but be opposite to those on the parts of the hands in contact with the weapon, so that the mechanical markings would fit into the human markings and a perfect fit of body and weapon be thus obtained. But the maker of a shot gun cannot achieve this ideal, because he does not have the pattern of the markings of the user's hands when designing the lines on the stock. Also, the human markings, like all human devices, are extremely complex, and could be

reproduced only with difficulty and at considerable expense. Also, no two wielders' hands have the same pattern of markings, and the weapon with markings corresponding to those on a wielder's hands would suit no one except the wielder for whom the markings had been cut. Furthermore, the user seldom grips the weapon twice in exactly the same way, and if the markings on the stock could be made to fit into those on the wielder's hands on one occasion they would not be likely to fit again at a subsequent time.

Although the maker of a shot gun does not attempt to make the chequerings correspond with any exactness to those on the hands, and has to be content with making a distorted and simple geometrical copy of them, yet on some primitive types of weapons markings are made which do correspond to those on the wielder's hands and fit them exactly. Markings corresponding to those on the wielder's hand are made on an Australian spear-thrower which has a lump of gum on its handle, *Figure 29*. If the weapon is grasped before the gum is quite hard, or when the gum is soft because of the heat of the sun or wielder's hand, then an exact impression of the markings of the wielder's hand is formed on the gum. The markings of the hand and those on the gum then of course correspond exactly and fit into each other, and a good grip is obtained. A new set of markings is made each time a grip is made, and so the weapon has the remarkable property of being automatically provided each time it is used with a set of markings which correspond to and fit exactly into the human markings of the hand of any person who wields the weapon. Clearly, the prototypes of the markings on a gun are the human markings on the parts of the hands and fingers in contact with the stock.

Markings of the hands and fingers are faithfully reproduced in mechanical forms on the handle of a cricket bat or tennis racket when the handle of the bat or racket is covered with rubber; for the pressure of the hand or hands causes deformation of the rubber so that it takes the impressions of the hand or hands. This partly explains why such a good grip can be obtained on soft rubber, and why the grip

feels sticky. The impressions on the rubber disappear after removal of the hand or hands, but this is an advantage, as new ones can be made each time the handle is grasped, to suit the new positions or forms of the human markings. A disadvantage felt as a result of the very close fit of the rubber markings and human markings is that there is no ventilation, for the rubber is not provided with pores corresponding to those of the skin to carry off moisture (Rule 6).

When the handle of a tennis racket is covered with a length of leather wound spirally round it, the chequering is human and formed only by the markings on the hand, unless the leather is soft enough to take the impressions of the human markings or lines. If the handle of a cricket bat, hockey stick, or tennis racket, is bound with a length of adhesive tape, the chequerings of the hands, i.e., the pattern of the lines of the hands, will be reproduced on the surface of the tape if the tape is soft enough. The gum on the tape tends to fill the human markings and receive their impressions; and a good grip is obtained. This type of grip somewhat resembles that of the Australian spear-thrower whose handle is covered with gum. The human chequerings, or "finger prints" and hand prints, are not plainly reproduced on the handle of a cricket bat or hockey stick when it is bound with twine or cord, as the binding is too hard to take the impressions of the markings in the hands and fingers, but perhaps microscopic examination might show they are sometimes faintly reproduced.

Chapter 41

THE CARTRIDGE

THE origins of the cartridge case can be traced back to the contrivance formed by the right hand and fingers of the archer as he holds the butt of the arrow. The cartridge case and the interior of the breech of the bow and arrow machine cannot be distinguished as separate contrivances. They have become separate contrivances in the gun machine, but for many years after the first making of fire arms no cartridge case was provided, and the interior of the breech had to serve also as a cartridge case. Even today the form of the interior of the cartridge case of a gun is nearly identical with that of the interior of the breech, and the case nearly coincides with the interior surface of the breech.

The cartridge case of the gun forms a type of mechanical skin for the interior of the breech and rear end of the back part of the barrel. The human prototype of the cartridge case is the skin of the right hand palm and parts of the fingers near the palm of the archer, that is the skin of the human breech and rear end of the back part of the barrel.

The right hand of the archer forms a bulbous or bottle-shaped contrivance on its interior, which has some similarities to the bulbous or bottle-shaped cartridge case, the neck of the human cartridge case being formed round the butt of the arrow.

Two parts of the cartridge case can therefore now be fairly clearly distinguished, one the narrow neck enclosing the butt of the arrow or bullet, and the other the bulbous part which encloses the power charge.

The cartridge case and breech chamber of the rifle machine are more regularly shaped than the corresponding contrivances of the bow and arrow machine. The fore part of the cartridge case of the gun completely surrounds the butt of the bullet, and the part in the breech chamber has a

regular bulbous form, unlike the human contrivance which is very irregularly shaped. The mechanical contrivances are distorted for several reasons. It would of course not be possible with advantage to make them in the human shapes for use in gun machines.

The cartridge case and breech chamber are distorted in shapes so that any section is a complete circle; and these contrivances thus become closed round the butt of the bullet and power charge, and the power can act only towards the mouth of the case and along the axis of the bullet and barrel. The breech is made very strong so that the case cannot expand laterally, although it can expand sufficiently to fill the breech chamber and seal the bore. The breech of the bow and arrow machine is also strongly formed at times, for when drawing the arrow the archer exerts much pressure on the butt.

As the cartridge case expands and seals the breech and barrel, it comes still more closely to the form of the breech and barrel, and thus automatically forms a more skin-like covering for their interior surfaces.

The breech face, or vertical face of the breech chamber, is formed in the bow and arrow machine by the part of the strings in contact with the butt of the arrow, or in the pellet bow machine by the back part of the pouch. The mechanical part of the breech block goes forward with the arrow or bullet, but its human counterpart, formed by the palm, does not go forward. The breech block of the gun does not go forward with the missile, but provides the force to drive the missile forward, for the exploding charge must press against it to drive the missile out of the barrel as a person standing against a wall must press against it if he wishes to propel himself suddenly from it, the wall acting as a kind of breech block and indirectly providing the power.

The wad and breech block are separate contrivances in the gun machine, but cannot be seen as distinct contrivances in the bow and arrow machine. The pellet of the pellet bow is driven forward directly by the back of the pouch; the butt of the arrow by the middle portion of the strings. The back

part of the pouch or middle portion of the strings, besides forming a mechanical breech block, corresponds to the wad of the cartridge of a gun, and is a prototype of it. The human prototype of the wad is usually some part of the palm or parts of the fingers near the palm, as becomes evident when the way a missile is thrown by hand is studied. The missile is driven forward directly by a thrust from the part of the human pouch against which it lies. Thus, if the missile is a stone or cricket ball, it will probably be held by the fingers against the part of the palm nearest the first two fingers and the lower parts of these fingers; and the thrust will be given by the device formed by these human parts. Similarly the wad of the shot or stone putter is formed where the first fingers and palm meet. The wad of the caber tosser is formed by both hands, since both hands give the thrust to toss the caber. When a sling is used, the human pouch is partly mechanized, and the wad is seen as the back part of the pouch which directly gives the thrust to drive the missile forward; and the right hand does not directly form the wad, which is now directly formed by the back part of the leather pouch, the right hand being partly released from the task of forming the wad (Rule 5).

The material of the wad of the pellet bow machine is usually leather or skin; that of the bow and arrow machine may be of hemp, sinew, rattan, silk, or other material, depending on the material of the middle portion of the strings or on the material with which the middle portion is wrapped. The wad of a shot gun cartridge may be of paper, tow, felt, or other similar materials. There is therefore some correspondence of materials between the materials of the wad of the bow and arrow machine and those of the gun machine, and when the pellet bow is used and the pouch is made of leather or skin between the materials of the wad of the pellet bow and the human wad of the stone thrower. A rifle cartridge may have no separate wad, and the power may act directly against the butt of the bullet; but a thin jute wad is sometimes placed against the base of the bullet.[1]

[1] Major Sir Gerald Burrard, Bt., D.S.O., R.F.A., *Forensic Ballistics.*

The fingers of the right hand besides forming the back part of the barrel and the mouth of the cartridge case of the bow and arrow machine grip the butt of the arrow and form a cannelure or stabbing device. It is not sufficient merely to enclose or partly enclose the butt. It must be held tightly. Similarly, it is not sufficient merely to enclose the butt of a rifle bullet; it must be gripped by the cartridge case. Usually a cannelure, or circumferential groove, is made in the butt of the bullet, and the end of the cartridge case is pressed into the groove; or the end of the cartridge case is stabbed in several places into the butt of the bullet, thus securing it to the case and to the breech. The action of pressing the end of the case into the circumferential groove or of stabbing it at several places into the bullet corresponds to the action of the archer in gripping, or stabbing, the butt of the arrow with his fingers. Similarly the action of turning over the ends of the cardboard cartridge case of a shot gun to hold the cardboard disk and thus to hold the pellets to the wad or charge corresponds to the action of the archer in pressing with his fingers on the butt of the arrow to hold it to the strings and power of the bow arms. The action of relaxing the grip of the fingers corresponds to the action of the turnover of the shot gun cartridge case or end of the cartridge case of the rifle in straightening to release the bullet or pellets; and the action of the arrow in moving forward from the human cartridge chamber corresponds to the action of the bullet or pellets in moving forward from the mechanical cartridge chamber.

It is evident that although makers of weapons have exercised their skill and ingenuity for several centuries to mechanize the breech and gripping devices, yet the principles by which bullets or pellets are held to the power mechanisms are the same as those by which arrows are held to the power mechanisms. Indeed, according to the human prototype theory, it is not possible to change these principles.

The power charge to drive forward a bullet is contained in the cartridge case. The power to drive forward an arrow from the bow is concentrated in the cartridge case or breech

chamber formed by the archer's fingers. The power from the bow arms is concentrated at and transferred to the middle portion of the strings, and especially to that portion in contact with the butt of the arrow, this part of the strings also forming the wad. As the archer makes his cartridge case with his right hand and fingers, he includes within them the wad or middle portion of the strings where the power becomes concentrated. The power to drive forward the arrow is therefore contained in the archer's cartridge case and breech chamber in much the same way as the power to drive forward the bullet is contained in the rifleman's cartridge case and breech chamber.

There seems little in common between a bow and arrow and a gun if these weapons are studied without reference to the wielding machinery, and few or no relationships can be seen between them. On the contrary, when the bow and arrow and hand gun machines are compared relationships can quickly and easily be established. It has been shown that many of the parts and devices of the bow and arrow machine are also parts and devices of the hand gun machine, and very little changed in form, and the changes that can be observed can be accounted for from the effects of further or less mechanization. The only part or device of the hand gun machine that has not yet been fully discussed is the power. At first, it may seem there is no relationship between the power obtained from bow arms and power obtained from gunpowder. The author has not yet been able to advance the study of weapons to a stage when it can be proved the power obtained from gunpowder is of the same nature as that obtained from bow arms, and that the use of gunpowder marks merely another and small advance in methods of mechanizing the offensive machinery. But certain reasons will be given in the next chapters which may incline the reader to think that there was no break in the process of mechanizing the offensive machine when gunpowder was used.

Chapter 42

CHARGING THE BOW

WHEN the ordinary bow is drawn, the charge, or amount of power, in the bow arms is exactly equal to the power exerted by the archer's body; and no greater power than can be exerted by the archer can be given to the bow arms. The missile of the ordinary bow machine is therefore propelled by one charge of the power of the archer's body.

An archer when he has drawn the strings cannot by repeating the operation put another charge into the bow arms, after the manner in which a cyclist can put another charge of air into the cycle's tyre by repeating the pumping operation, because the bow becomes uncharged as he reverses the operation of drawing the bow, and drawing the bow a second time merely recharges it with a similar charge to that previously given.

To draw the ordinary bow several devices or contrivances are formed by the archer's body. The right hand fingers curl partly round the strings and form a claw device to grasp them. The right arm forms a drawing-arm device to draw the claw device. The left arm forms a rod or pole device to keep the bow handle at arm's length as the strings are drawn. The left hand and the bow handle together form a device to connect the rod or pole device to the bow arms. Probably many other devices and contrivances are also formed.

When the archer lies down to shoot, the claw device is formed by the fingers of both hands, and the drawing-arm by both arms. If he places one foot against the handle, the pole device is formed only by one foot, but if he places both feet against it, the device is formed by both feet.

If the archer stands to shoot, the drawing-arm pulls the claw device along the pole device formed by the left arm.

If he lies down to shoot, the drawing-arm pulls the claw device along the pole device formed by one foot or both feet. The machinery which operates the drawing-arm is formed by the body. It is extremely complex, and little can be discovered about it by direct observation only of the bow machine. But it can be seen, in a general way, that when the archer stands to shoot, the power to draw the drawing-arm is obtained by separating the hands and expanding the chest; but when he lies down to shoot, the hands remain together, and power is obtained by straightening the body.

The strings of the earliest crossbows were drawn in much the same way as the strings of the ordinary bow are drawn by the archer who lies down to shoot. The crossbowman, like the archer, placed his feet on the bow arms, and drew the strings with the claws formed by his fingers and the drawing-arm formed by his arms. The wooden stock was not of much use until the strings had been fully drawn, when, instead of continuing to hold them, the crossbowman slipped them over a catch or into a groove in the stock. The pole device until the strings were fully drawn was formed by the feet, but after they had been drawn by the wooden stock. The charging appliance of the crossbowman, like that of the archer, was formed entirely by the body, and possessed no mechanical parts.

The strings of some modern crossbows are similarly drawn by hand. The Fan crossbow, for example, is drawn by hand. To draw the strings the Fan crossbowman sits down on the ground, puts his feet against the bow, and hauls the strings with his hands into the notch on the stock, *Figure 41*, which holds it until it is released by the trigger. But many types of crossbows can be drawn only with the help of mechanical appliances. Appliances commonly used are:—

The belt and claws
The belt, claw, and pulley
The goat's foot lever
A lever incorporated in or hinged to the stock
The screw and handle
The wooden lever

The windlass
The cranequin

By means of mechanical appliances the drawing machinery of the wielder's body is partly mechanized, as will now be explained.

The claw and the drawing-arm devices are partly mechanized when the crossbow is drawn with the help of a belt and claws.* The device formed by the foot and bow handle is also partly mechanized by means of the stirrup fastened to the fore end of the stock, *Figure 58*. To draw the strings the crossbowman places a foot in the stirrup, and the claws under the strings, and then straightens his back. The strings are slipped on to a catch on the stock, and the claws are unhooked, and the crossbow is then ready to receive its quarrel.

FIG. 58.
CROSSBOWMAN WITH BELT AND CLAWS
Viollet-le-duc

At the moment of placing the metal claws round the strings the crossbowman's fingers and metal claws are in contact; and the claw device is then formed partly by the metal claws and partly by the crossbowman's fingers. The human part of the device of course must guide its mechanical counterpart into its place round the strings. When the metal claws are in position, the human part of the device is removed and transferred to the end of the cord near the belt. The claw device, however, is still formed partly by the human claws; and the metal claws at one end of the cord

*For descriptions and illustrations of appliances for drawing crossbows see:—

Sir Ralph Payne-Gallwey, Bt., *The Crossbow;*

A. Demmin, *Arms and Armour;*

Colonel C. L. Spencer, Glasgow and West of Scotland Society, 17th Jan. 1907;

M. Viollet-le-duc, *Dictionnaire Raisonne du Mobilier Français;* etc.

and the human claws at the other end together form the complete device.

The drawing-arm at first is formed only by the crossbowman's arms; but after transferring the human components of the claws to the end of the cord near the belt, the drawing-arm is formed partly by the cord and partly by the arms. The cord gives the arms a flexible extension, and is evidently a crude mechanical extension of the cords of the arms.

The foot instead of being placed directly on a bow arm is placed on the bar of the metal stirrup, which evidently is an extension of the device formed by the bow arm when a foot is placed on it. The use of a stirrup prevents injury to the fastenings which join the stock to the bow arms, through abrasion by the ground. It also allows the crossbowman to use the power of his body to greater advantage by allowing his foot to be more extended.

The crossbowman's hands are not separated during the drawing of the bow strings, and power to draw them is obtained by straightening the body. The machinery which pulls the drawing-arm and claws is formed entirely by the body. This machinery is extremely complex, and cannot be studied directly; but some of its features can be discovered by studying appliances like windlasses and cranequins. The belt and claws appliance gives no mechanical advantage, and only one charge of the power of the body can be put into the bow arms by means of it.

Two charges of the power of the body can be put in the bow arms when the crossbow is drawn with the help of a belt, pulley, and claw. When this appliance is used, one end of a cord is hooked or fastened to the belt, and the other end is hooked to the stock near the butt. The cord passes round a pulley, and the hook of the pulley is placed round the bow strings. The crossbowman places a foot in the stirrup, and by straightening his body draws the strings on to the catch. The cord and pulley are then unhooked from the stock and bow strings, and the crossbow is ready to receive its quarrel.*

* Crossbows being drawn with belts, pulleys and claws, can be seen in the picture, "The Martyrdom of S. Sebastian," by Pollajuolo, in the National Gallery, London.

The hook of the pulley somewhat resembles a bent forefinger, and to fit it to the bow strings the crossbowman's finger is placed against it, and is kept near it as the strings are being drawn. The mechanical and human parts of the claw device therefore remain together during the drawing of the strings, and the human part is not removed and transferred to the end of the cord near the belt as when the appliance described above consisting of a belt and claws but no pulley is used. The proximity of the forefinger to the hook reveals that the hook and forefinger device are closely related, and that the prototype of the hook is the forefinger claw. The metal claw is much stronger than its human counterpart, and relieves it of the task of directly grasping and drawing the bow strings. The human part must guide the mechanical part and neither part can be used without the other.

The drawing-arm is formed partly by the cord and partly by the crossbowman's arms. The part of the cord between the belt and the pulley forms a flexible extension for the right arm, and nearly relieves it of the task of directly exerting power to draw the strings. The part of the cord between the pulley and butt of the stock acts as a flexible extension for the left arm. The left arm presses on the butt end of the stock; and the left arm and wooden stock together help to form the pole device to keep the bow arms near the foot as the strings are being drawn, the stock being nearly in line with the left arm and forming a rigid extension for it. The pole device is also formed partly by the right leg which has no mechanical extension and acts directly on the bar of the stirrup.

During the drawing of the strings the right hand moves towards the left hand a distance equal to the draw of the bow, which is usually much smaller than the draw of an ordinary bow and may be only a few inches. Power is obtained therefore not by separating the hands and expanding the chest, but by making the hands approach one another and by contracting the chest, actions which are the reverse of those performed when a standing archer draws his strings.

Because the actions are reversed they are therefore similar. The crossbowman also straightens his body as he draws the strings; and this action is similar to that used when an archer lies down to shoot.

The use of a pulley gives a mechanical advantage of two to one. A more powerful bow can be drawn therefore with the help of this appliance than can be drawn by the help of the appliance previously described, and two charges of the power of the crossbowman's body are put into the bow arms when the strings are fully drawn. The crossbow cannot become uncharged when the crossbowman relaxes, because the strings are then held by the revolving nut or other catch on the stock.

Horsemen could not use a belt and claws, or belt and

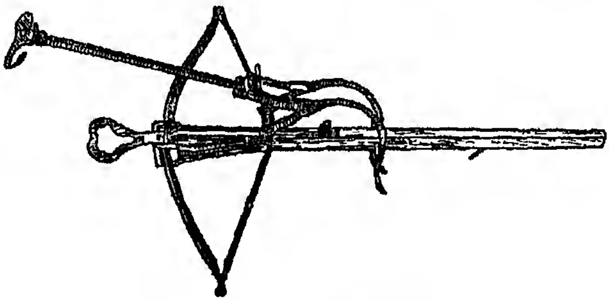


FIG. 59. GOAT'S FOOT LEVER ON A CROSSBOW
Viollet-le-duc

pulley and claw; but could use a goat's foot lever, so called from the resemblance of its prong to the hind foot of a goat. The prongs are placed over pegs which project from the sides of the stock. The two claws of the lever catch the strings, and the crossbowman places his left hand under the stock, and his right hand grasps the end of the lever and pulls it back to draw the strings on to the nut or other catch on the stock. At the end of the lever there is a plate and hook for fastening the appliance to the belt before and after use.

By means of a goat's foot lever a crossbow is drawn in much the same way as a bow is drawn when the archer stands

to shoot; for the hands are separated and the chest is expanded to charge the bow arms. Before drawing the strings the crossbowman's right hand is forward, and it is drawn back as the strings are drawn. His left hand remains stationary under the fore part of the stock. The foot is not usually placed in the stirrup, which is used mainly for hanging the weapon on a wall. The weapon is held about horizontally; and the stirrup and foot device, or one corresponding to it, is formed by the pegs over which the prongs are placed and by the prongs.

The metal claws relieve the human claws of the need for directly grasping the strings (Rule 5). The human part of the claw device is formed probably by the right hand claws which grasp the end of the lever. The drawing-arm is formed by the parts of the prongs and claws between the pegs and bow strings. The right arm is given a rigid extension by means of the handle of the lever.

A lever is incorporated in the stock of some crossbows, as in the stone-bow and bullet-shooting crossbow, or jointed to the stock as in the Chinese repeating crossbow. The stirrup and foot device is formed by the peg and hole, where the lever is hinged to the stock. To draw the strings of a bullet-shooting crossbow, the left hand is placed under the stock which is held about horizontally, and the right hand palm presses the button at the end of the lever, the hands separating somewhat as the lever is pressed down into the top of the stock. When the strings are fully drawn, the lever lies in and becomes part of the top of the stock and butt. The claws which draw the strings are found in mechanical form as the metal finger which hooks into the back of the pouch at the middle of the strings.

Some crossbows are drawn with the help of a long screw in a hole drilled in the stock. The hole is drilled from the butt through the length of the stock until about the lock. At its fore end the screw bifurcates into two claws which grasp the strings. A handle is screwed on where the screw emerges from the butt; and by turning this handle the long screw is gradually pulled through the hole in the stock until

the strings are fully drawn. The claws are mechanized by the claws of the screw, and the drawing-arm by the screw itself; and the actions of an archer's arm and claws are crudely reproduced as the screw draws the claws towards the butt.

Some crossbows are drawn with the help of a simple type of wooden lever. The handle has a hook which is placed in a small stirrup at the fore end of the stock. A piece of wood is hinged to the handle a little distance above the hook, and its end opposite the hinge is placed against the bow strings. To draw the strings the right hand is placed at the end of the lever, and the lever is drawn towards the crossbowman. As it is pulled towards him, the hinged piece of wood pushes the strings along the top of the stock on to the catch. The claws are formed by the parts of the hinged piece of wood in contact with the strings, and the drawing-arm by this hinged piece of wood. The arm is given a rigid extension by means of the handle of the lever.

The windlass is a complicated appliance consisting of claws, pulleys, and cords, with a kind of box to fit on to the butt of the crossbow. The crossbowman places his foot in the stirrup and winds the cords until he can place the claws on the bow strings. He then winds the cords until the bow strings are on the catch. The appliance is then removed from the crossbow, and the quarrel is placed in position.

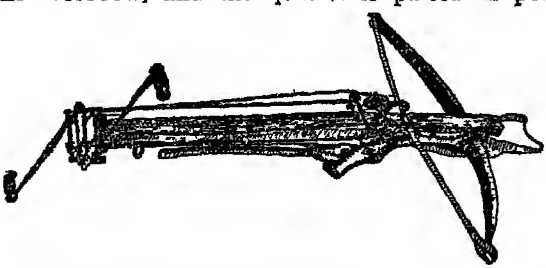


FIG. 60. MILITARY STIRRUP CROSSBOW, XVIth Cent.
Glasgow Art Gallery and Museums
(From a photograph)

The claw device, as the claws are placed on the strings, is formed by the metal claws and by the human claws. After

the claws have engaged the strings, the human claws are removed and placed on the bars of the handles. The human claws, however, still form a complementary part of the device, as can be understood from the fact that the human claws on the handle bar must provide the force to draw the metal claws. The drawing-arm is formed by the cords of the windlass, which shorten as they draw the metal claws along the stock. The cords act as flexible extensions of the cords of the arms. The arms of the crossbowman are given rigid extensions by means of the handles of the windlass. The handle bars fill the hollows of the fists. The foot and stirrup device is in two parts. One part is formed by the foot and stirrup, and another part by the box at the butt, which is a transferred mechanized part of the device. The two parts are at opposite ends of the stock (Rule 8). Very powerful crossbows can be drawn by a windlass; and several charges of the power of the wielder's body can be put in the bow arms with its help.

The cranequin is a cog and ratchet appliance. The stirrup at the fore end of a crossbow made to be drawn by a crane-

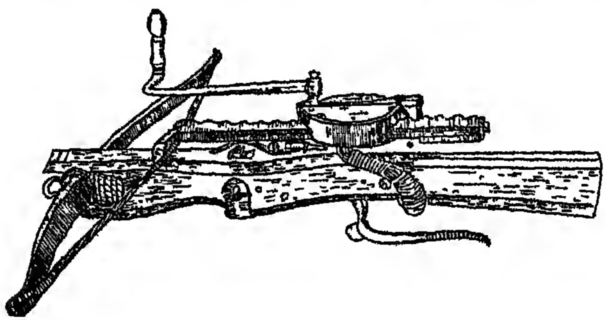


FIG. 61. CRANEQUIN ON A CROSSBOW
Viollet-le-duc

quin is usually too small for a foot to be placed in it, and is used for hanging the weapon on a wall or on a saddle, and not for drawing the strings. The foot and stirrup device is formed by the pegs which project from the sides of the stock

and the thick loop of cord or rope which goes round the stock. To use the cranequin, the butt of the stock is pushed through the loop of cord or rope, and the cranequin is drawn along the stock until further movement is prevented by the loop coming against the pegs. The cranequin is unwound sufficiently for its claws or fingers to engage the bow strings, and then wound until the strings are drawn on to the catch. A few reverse turns of the handle release the claws from the strings, and the cranequin is then drawn off the stock.

The human arms which draw bow strings are mechanized by means of the ratchet-arm of the cranequin; and the action of the human arms in pulling the bow strings towards the body is approximately reproduced by the ratchet-arm as it is drawn back along the stock. The human claws are mechanized by means of the claws of the cranequin.

The charging machinery is only slightly mechanized by means of a cranequin, for the human arm must turn the handle and the body must generate the power. Human actions also are required to place the cranequin on the stock and remove it.

The actions of the crossbowman when the cranequin is used somewhat resemble those of an archer who shoots standing. As the handle is turned the hand is brought back and then pushed forward; and several charges of the power of the body are given to the bow arms. The cranequin gives great mechanical advantage and very powerful crossbows can be drawn with its help. It is indeed as powerful as a motor car jack, and is constructed on the same principles.

Usually the handle of a cranequin is about 9 inches long, and about 30 turns of the handle are needed to draw the strings.[1] The strings of a crossbow are drawn back only about five to seven inches; and the draw of a crossbow is therefore much less than that of an archer's bow.

An archer may draw the strings with two fingers, or with three fingers, or with four fingers, or with the thumb alone; but if he draws the strings with two fingers, he uses the same two fingers to form the catch and uses them to effect the

[1] Sir Ralph Payne-Gallwey, Bt., *The Crossbow*.

release. Similarly, if he uses three fingers, or four fingers, or the thumb only, to draw the strings, he uses the three fingers or the four fingers or the thumb alone to form the catch and to release the strings. In other words, the fingers which are used in the charging appliance are used also to form the catch and trigger devices, for the archer does not change his fingers after drawing the strings. When the charging machinery is mechanized, the number of its mechanical claws usually corresponds to the number of the mechanical claws, or fingers, of the catch and trigger devices of the crossbow for which the charging appliance is made. When a belt and claw are used, the claw may have one or two fingers, and will usually be drawn back on to a catch having one or two fingers to correspond. The goat's foot lever has two claws, and crossbows which are drawn by it usually have a catch with double fingers. The mechanical catch and release devices of a crossbow are formed by the same mechanical finger or fingers, and, therefore, the number of fingers of the devices must necessarily be the same. The lever of a bullet-shooting crossbow has a single metal finger which draws the strings, acts as the catch to hold them in the drawn position, and acts as the releasing device, and therefore the charging appliance and the catch and release devices have each the same finger. Windlasses and cranequins usually have two fingers, or claws, for drawing the strings, and usually draw them back on to a catch having two fingers, or claws.

Certain advantages are gained, but corresponding disadvantages are felt as a result of partly mechanizing the charging machinery. A stronger bow can be fitted, and a greater charge can be given to the bow, and the strings can then exert a greater pressure on the butt of the missile to drive it forward; but more time is needed to bring the weapon into action. To fit and wind up a windlass needed so much time that the crossbowman found himself at a disadvantage compared with the longbowman, who could fit and shoot several arrows while the crossbowman was fitting his windlass and winding his strings; and to protect himself while winding his

crossbow, he was sometimes compelled to place a pavise, or large shield, in front of himself. Also, the archer's charging machinery, being formed wholly by his body, cannot be mislaid and is always ready for use. The windlass may be mislaid, or its mechanisms may get out of order. Furthermore, the archer's charging machinery exists ready made for him; the windlass must be manufactured, and its manufacture requires much time and skill.

As mechanization proceeds, the time needed to charge the offensive machine increases. The wielder of the fist in a few seconds can provide the power to drive forward a fist. The archer requires a slightly longer time to charge his bow. Types of crossbow machines with windlasses or cranequins require a long time to charge, because the winding appliance must first be made and then be fitted to the crossbow. To charge the gun machine requires a very much longer time, however, than to charge any type of crossbow machine. The time required to charge the gun machine is not, of course, the time required to put in a ready made cartridge. It includes the time required to mine and refine and manufacture the metal of the cartridge case, the time required to assemble the ingredients of the explosive, the time to mix them, the time to fill the cartridge, and the time to hand it to the gunner.

CHAPTER 43

GUNPOWDER AND CANNON

THE archer's or crossbowman's arms are partly mechanized and given mechanical extensions by means of the bow arms of the weapon; and by studying the bow arms and their actions some things can be learnt about the human wielding arms as they are formed when wielding a bow or crossbow.

But the human arms or mechanical arms are not the source of the power that gives a blow or thrust. The arms, human or mechanical, are parts of the power machinery but the main parts are formed farther back in the body itself. But how the power is generated, stored, and released, is almost entirely unknown. In a general way it can be said the power is obtained from food, water, and air, taken into the body. Some process of combustion of these materials occurs, from which energy is obtained. Various mechanisms of the body store the energy, others make it available for release, and others release it in the amounts required. Probably it is not possible, except in a general way, to know much about the power machinery of the body by direct study of the body.

Human types of the offensive machine, like the fist or claws machine, release their power noiselessly. The ordinary bow and arrow machine also delivers its power almost noiselessly, except for the twanging of the bow strings. The Andaman bow and arrow machine however is noisy in operation, and "one of the chief drawbacks to the bows used by these tribes is that they cannot be fired in silence, in consequence of the string striking the lower or convex portion of the weapon." [1] When a bow is bent, some parts of the wood

[1] E. H. Man, *On The Aboriginal Inhabitants of the Andaman Islands*.

are in a state of compression, others in a state of tension; and it seems the elastic power is stored by the compressed and extended parts, and released as they resume their natural states. If the bow is bent too much it may break, and as it breaks a sharp crack or explosive noise is heard. The materials then of course cannot resume their natural states and deliver power. The explosive noise as wood is heated and bent can be heard when sticks are placed on a fire, and the cracks or explosions are often accompanied by the emission of sparks and smoke. The ways the elastic powers of materials are stored and released are little understood; but probably the power of gunpowder is a type of elastic power related to that obtained when a bow arm is bent, and the release of the power of the gunpowder is also probably similar to the release of the elastic power of wood.

The hand gun machine differs most markedly from the bow and arrow and crossbow machines in not having bow arms and strings fastened to it. But the absence of bow arms and strings, as has been stated, can probably be accounted for as a result of their transference away from the wielders and weapons into the factories which generate the power for the gun.

Mixing gunpowder was a tedious and laborious business; and to lighten his labours the mixer often suspended the pestle from an elastic wooden arm projecting from a wall or over a beam, the arm being fixed nearly at right angles to the wall. The elasticity of the mechanical arm raised the pestle and thus lightened the work and made it easier. The mixer's arm was given artificial extensions for its rigid and flexible parts by means of the wooden arm and the cord. The wooden arm and cord with the pestle and mortar can be seen in many illustrations of old time chemists' and alchemists' workshops.

Illustrations of early methods of making gunpowder in factories show contrivances which it seems are types of bow arms and strings suspended horizontally from walls to which the pestles were fastened.* When stamp mills superseded

* See Oscar Guttmann, *Monumenta Pulveris Pyrii.*

these early factories, the bow arms were still evident. Probably they can still be found in modified forms in modern factories. Early pestles were sometimes also worked by pulleys or other winding devices which were probably forms of the windlasses and cranequins of crossbows.

The windlass, cranequin, or other apparatus, together with its human counterparts, forms a single machine for transmitting the power to the crossbow's bow arms. After the power is stored in the bow arms, the winding apparatus is removed and may become far separated from the crossbow. Thus the crossbowman can wind up his weapon at home, and some time later when far from home release the power. It is indeed not necessary for him to generate his own power; some one else can charge his crossbow for him; and he can then propel the missile with power generated by some one else or by others. The beginnings of the factory system for generating and winding the power can be seen in this procedure.

The wielder of a gun does not nowadays as a rule generate his own power, and others do it for him; and the generating and winding machinery is kept in the factory. In the early days the winding machinery in factories was fairly simple, and probably formed by machines whose parts corresponded to the parts of windlasses, cranequins, goat's foot levers, bow arms, and other parts of the winding appliances that were used in winding the power of crossbows. Nowadays the machines have been considerably modified and made much more complicated; but probably they still retain the same principles. No new principles are involved when the power is generated away from the weapon; for when the winding apparatus is placed on a crossbow, the stock and other parts temporarily act as parts of the apparatus, and the contrivances they form can be easily copied by contrivances in the factories.

When gunpowder was discovered and used as a propellant it seems some of the power mechanisms of the body were partly mechanized in a very crude and elementary way. It seems also that by the use of atomic power for weapons the process of mechanizing the power machinery has been

advanced another step; and the use of atomic power reveals that the power of the body is obtained by atomic processes.

Great difficulties were at first experienced in controlling and directing the power of gunpowder, and it was many years before the disturbances of the offensive machine due to further mechanization of the power machinery could be even partly rectified. But gradually the mechanical stock, barrel, sights, and other parts and devices, were assembled with and correlated to the mechanical power and came into their proper places. Eventually even the trigger, trigger spring, and other parts of the lock, took their places in the hand gun machine in much the same places as in crossbow, bow and arrow, and human machines.

If an entirely new principle had been introduced by the use of gunpowder, then we should have expected that the aiming attitude of the rifleman would never and could never be similar to that of the archer or wielder of the fists. Yet, sometimes, the attitudes of a rifleman and archer when aiming and of the wielder of the fists are very similar. The introduction of gunpowder as the propelling force for the missile has not considerably altered the offensive attitude. It has not altered, to any degree, the way the missile is sent from the right hand to the left, for the missile is still sent in a direction from the right hand to the left when a rifleman shoots. It has not much altered the way direction and elevation are obtained, for the rifleman obtains his direction by placing one foot in front of the other towards the direction of the target, and his elevation by raising or depressing his left hand, exactly as the archer or wielder of the fists obtains his direction and elevation, and has obtained them from time immemorable. It has not relieved the rifleman's body of the need for forming a stock to support the weapon, and act as a pivot or turn-table as he changes the direction of his aim. The use of gunpowder indeed has caused few or no real changes in the manner of propelling a missile.

The further mechanizing of the power machinery by the use of atomic power has once again occasioned confusion in the development of the offensive machine, and at present the

new power cannot be combined with the mechanical stock, barrel, lock, and other parts; but no doubt in a few centuries, as happened after the discovery of gunpowder, parts will be reassembled and the wielder of an atomic hand weapon will deliver his blow or thrust in a manner similar in principle to that in which the archer, the clubman, or the wielder of the fists delivers his blow or thrust.

The mechanisms of a hand gun are probably mainly mechanical extensions of the human mechanisms of the wielder. But those of a cannon or great gun are probably mechanical extensions of the mechanisms of all the wielders, that is of all those who operate it. The shaft of a spear, the handle of a club, and various parts of other weapons, have been shown to be mechanical extensions often of both arms or both fists, the larger girths or bulks or weights of the parts being thus accounted for. Somewhat similarly, a great gun is probably a mechanical extension of the offensive mechanisms of all its gunners; and also, since the power is generated in factories, of parts of the offensive mechanisms of the workers in the factories.

But to show that the parts and devices of a great gun are related to the offensive mechanisms of many people is difficult and much research work would have to be done to prove or disprove this belief. But the following remarks may help to show the probable truth of the belief.

The Chinese repeating crossbow may be wielded by one person, but often a boy is employed to feed arrows into its magazine. The boy's body then supplies parts of the offensive machinery, and his mechanisms work in harmony and co-operation with the mechanisms both of the crossbow and of the crossbowman. The crossbow then becomes a mechanical extension not merely of the offensive mechanisms of one person but of two persons. Similarly, when a machine gun is worked by two or more persons, as it usually is, it is a mechanical extension of the offensive mechanisms of two or more persons, as the case may be. The maker of the machine gun, of course, has so arranged its mechanisms that they can form extensions of the offensive mechanisms of

more than one wielder. Usually the weapon is made to be worked by a definite number of men, each of whom has his place near the weapon, and must contribute his particular actions; and when the machine gun is in action, all its parts and devices work in harmony with those of its wielders and form extensions of parts and devices of the wielders' bodies.

Human mechanisms can be distorted to some extent, so that, for example, the Chinese repeating crossbow can be operated by one man or by a man and a boy. When it is operated by one man, his body supplies the human counterparts of the weapon, but when it is operated by a man and a boy, the mechanisms of the bodies of the man and the boy supply the counterparts. But when a weapon designed to be operated by a definite number of men is operated by more or less than that number, the human mechanisms are under some strain and become distorted. Human mechanisms, of course, are under some strain and are distorted when any mechanical weapon is being wielded, because the mechanical weapon is an imperfect extension of parts of the body, and the human mechanisms must distort themselves to form counterparts for the weapon. Distortion is reduced when the weapon is well designed and especially if it is made for a particular person.

Ways in which the human body can distort itself can be seen when a person wears boots or shoes too small for him or clothes that do not fit well. Parts of the body are then distorted in attempts to use the wearing apparel. Ideally boots or shoes or other wearing apparel should be made for the wearer so that there may be close correspondence between parts of the body and the wearing apparel. Makers of weapons like to know the dimensions and physical peculiarities of the wielder for whom a weapon is made—incidentally thus showing a belief in the human prototype theory, or theory that a weapon is made to fit the body—so that the dimensions of the parts of the weapon may be designed to suit the wielder. Thus, for example, the maker of a shot gun or rifle makes the butt of a length to suit the reach of the arm of the wielder, and provides a shorter butt

for a wielder with a short reach of arm than he would provide for a wielder with a longer reach. If a hand gun with a long butt is wielded by a man with a short arm, he will not be able to reach the trigger comfortably, and will have to distort parts of his body to operate the trigger.

A cannon or great gun is not a hand gun, and is made to be wielded by several men; and its parts and devices are mechanical counterparts of parts and devices of all its wielders. The barrel, for example, does not form a mechanical extension for the barrels of the hands of one wielder, but for those of all its wielders, and possibly also for those of the hands of the people in the factories who generate the power of the weapon. The barrel of a cannon resembles the barrel of a rifle and has similar actions. The breech and missile and many other parts and devices also are merely modified forms of parts and devices of the rifle. There can therefore be no doubt that a cannon is a mechanical reproduction and extension of the human offensive machinery. But it is most unlikely that it can be a mechanical reproduction of parts of the human offensive machinery merely of the gunner who applies the match or pulls the lanyard or presses the trigger or button to set free the power to propel the missile. It does not seem possible that distortion can be pushed to such a degree as to allow parts of the offensive machinery of one person to be given such massive mechanical extensions. It is true the barrel and breech and missile can be distorted very greatly, as is the case for example in the caber tossing machine whose missile is larger in bulk than that of most great guns; but distortion has made this machine almost useless for offensive purposes, although it has important uses as a demonstration machine for purposes of study.

The degree to which distortion can be carried is well illustrated in the lock actions of crossbows. An archer with the catch formed by his fingers cannot conveniently restrain a power much above 80 lbs. weight. But when the catch is given a mechanical extension by means of seers and springs and other devices, a crossbowman can restrain a power many

times this weight. According to T. T. Hoopes, "The cross-bow's catch was obliged to restrain a force of five tons or more, yet to hold this tremendous force in such easy control that it could be released to speed the arrow on its way with a slight pressure of the fingers."[2] Thus, by mechanizing the lock, the restraining power of the fingers can be greatly magnified, yet without imposing any strain on the fingers.

The principle of the shell which explodes on hitting the ground or after a certain time can be simply explained thus:—

The mechanical part of the fist is transferred to the end of the trajectory when a stone is thrown by hand, in accordance with Rule 8. When an arrow is shot from the bow, mechanical counterparts of the fist and arm and human riflings and other human parts and devices are transferred to the end of the trajectory. When a harpoon is shot from a bow its head becomes detached from the shaft immediately the creature is hit. Various parts and devices can therefore be transferred to the end of the trajectory opposite the wielder of the weapon. Part only of the power charge is set free when the shell is fired from the barrel of a gun, and a certain proportion of it is carried with the shell to the end of the trajectory to be set free there, either immediately or after a certain time. Certain parts of the timing or percussion devices are also transferred, so that this can be done.

The principle of the time shell is not unlike that of the fishing hook in some respects. The fisherman transfers a barb to the end of a mechanical extension of his arm or arms, and throws it with an attractive bait into the stream or pond. It may be a considerable time after the casting of the line before the fisherman operates the holding mechanisms by pulling on the line to hold the fish. The fish in this case supplies the timing mechanisms. The rod forms an extension for the rigid and for some of the flexible components of the arm or arms, as is evident when it is wielded by an expert fisherman.

[2] Article, The Double Set Trigger, in *A Miscellany of Arms and Armor, Arms and Armor Club, New York.*

The recoil machinery of the great gun is partly mechanized by the springs, buffers, or other contrivances which absorb the shock of the recoil and transmit it to the ground and restore the weapon to its original position. The repeating machinery is usually very little mechanized, and often is nearly wholly human, the gunners lifting the spare missiles and placing them in the breech and closing the breech. It is much less mechanized than the repeating machinery of the Chinese crossbow or rifle machine. The recoil machinery of the great gun machine however is usually more mechanized than that of the Chinese crossbow or rifle machine, neither of which has any mechanical contrivances like springs or buffers to take the recoil and restore the weapon to the aiming position.

The fact that the recoil machinery of the great gun machine is more mechanized than that of the Chinese crossbow machine but its repeating machinery is less mechanized shows that the process of mechanization of parts and devices of the offensive machine is not uniform. Thus, for example, the Ba-kwiri crossbow has been developed mechanically sufficiently to possess a five foot long barrel of cylindrical section and a butt which somewhat resembles that of a European musket complete with a small of the butt for the hand to grasp, and yet has such a primitive type of release that the power must be released by the fingers pushing the strings out of the notch in the stock. There has therefore been no uniform mechanical development of the barrel and stock and release mechanism. As another example, the modern rifle has been developed sufficiently to possess a barrel of circular section, stock, butt, magazine, sights, and many other mechanical parts and devices, and in addition the power charge has been developed to a considerable degree by the use of gunpowder, cordite, or other explosive, and yet the recoil mechanisms are completely unmechanized and must be supplied by the body. The fact that there are no mechanisms to take the shock of the recoil of a rifle is indeed made painfully evident to the wielder if he does not hold the weapon correctly to his shoulder so that the body

can form and supply the recoil mechanisms effectively, and some practised sportsmen even find it advisable to use a pad or other type of mechanical shock absorber between the heel-plate and shoulder. When a pad is used, of course, the recoil machinery is slightly mechanized.

When any part or device is further mechanized, other parts and devices usually suffer retrogression in mechanical d velopment, and many of them revert completely to human forms. The tendency of some mechanized parts and devices to revert to human forms when others become more mechanized is well illustrated in the development of the early gun or cannon machine.

When the power was further mechanized by being obtained from gunpowder instead of from bow arms, the barrel and breech were mechanized by means of the cylindrical tube sealed at one end. The stock and butt were also crudely mechanized by means of the trestle or other contrivance on which the cannon rested. But the sights, trigger, trigger

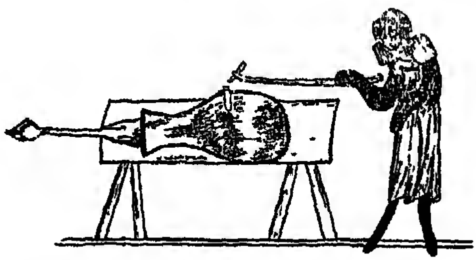


FIG. 62. EARLY CANNON, C. 1313 A.D.
By permission of the Governing Body of Christ Church, Oxford
(From a photograph.)

spring, and most other parts of the lock, chequering, chamfering, cast off and cast on devices, and many other parts and devices, reverted to human forms and had to be formed by the gunners. Many other parts and devices became almost atrophied. The rifling, for example, became nearly atrophied, and for centuries no means could be found for effectively spinning the missile. Probably the further mechanization of the power by use of atomic power will cause most of the

parts of the offensive machine to revert to human forms or to become nearly atrophied. That this is so is proved by the fact that an atomic bomb has to be lifted and placed in an aircraft and be aimed and released by human mechanisms. Probably gradually as centuries pass the human parts and devices now mechanized in rifle and other gun machines will also become mechanized in the atomic gun machine.

No doubt it was because so many parts and devices of the offensive machine reverted to human forms or became nearly atrophied that people were deceived into assuming that a new method of propelling missiles had been discovered and that new principles were involved when fire arms were first made, for it became difficult to see relationships between fire arms and previous types of weapons. Much the same thing is happening today. People are being deceived into assuming that the discovery of ways of further mechanizing the power, by making use of the power of the atoms of materials has resulted in producing new types of weapons. But as has been stated, and as the discoveries, which number many hundreds, revealed in this work show, no new weapon can be invented; and the human offensive machine was the first atomic weapon and is still the only perfected one.

The trajectory or range of the offensive machine can be much extended by mechanization. The range of the human offensive machine is not greater than the reach of the hand or fist. The range of the wielder of a club is about equal to the length of his arm and its mechanical extension. The range of some varieties of the thrusting spear machine may be sixteen or seventeen feet or more. The range of the simple stone throwing machine is a few hundred feet. The longbowman can shoot about three hundred yards, and the Mongolian archer can send a flight arrow eight hundred yards or more. The rifleman can throw about a couple of miles. The great gun machine can throw its missile to about 150 miles, which seems to be about the greatest range the gun machine can be made to have. A way of increasing the range almost indefinitely was discovered when a bomb was placed in an

aeroplane. The aeroplane is not an offensive contrivance but can be used as one, and by making use of it the range can be increased without apparent limits.

A result of carrying bombs in aircraft is to distort the shape of the trajectory, which is parabolic for many types of the offensive machine, although not for all. It is not parabolic, for example, in the case of the boomerang machine, and it is straight in the bowls, billiards, and croquet machines. The trajectory when a bomb is carried in an aircraft becomes flat and even wavy for much of its length. The end of the trajectory, however, is always parabolic, for a falling bomb describes part of a parabola. When the aeroplane is taking off, the trajectory is often nearly parabolic.

CHAPTER 44

THE COMPOUND BOW

THE self bow and the composite bow of the archer are used in modified forms by the crossbowman. But the crossbowman also uses the compound bow. This is a bow constructed on the principle of the carriage spring,

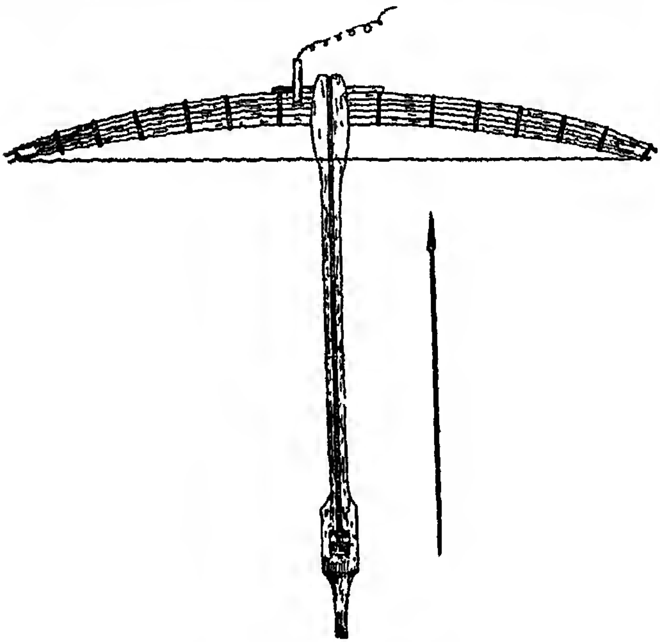


FIG. 63.
MALABAR CROSSBOW, WITH HARPOON AND LINE
Horniman Museum

and consists of plates which bend flatwise when the bow is being used. The Chinese repeating crossbow has a compound bow, made from three flat pieces of bamboo, which overlap each other, the shortest of the three plates being on

the inside of the bow. The Malabar harpoon shooting cross-bow has a compound bow, made from five pieces of wood loosely held together at intervals along the length of the bow by bands of string, Figure 63.

Although the compound bow and composite bow might seem at first sight to be constructed on different principles, there are certain close relationships between them, and one type of bow is a modified form of the other. The heart, or core, of a composite bow is often made from thin flat strips of horn or whalebone, and as many as twenty strips may be used. They are glued together to form a solid mass, and cannot move relatively to each other. The strips are not bent flatwise, but edgewise; and compared with the plates of the compound bow are turned through a right angle (Rule 10). The plates of a compound bow are not glued or rigidly fastened together, and can slide slightly along each other along their own lengths, after the manner of the plates of a carriage spring.

A compound bow with three plates has three components which work together to pull the strings. A composite bow with twenty plates has twenty components to work together to pull the strings; and each plate contributes its power somewhat after the manner in which each arm of a tug-of-war team contributes its power to pull the strings, or rope.

The hands of the members of a tug-of-war team form a barrel and breech for the rope. The barrel and breech are formed in much the same way as for a thrusting spear shaft; but when there are, say, eight men in a team, the barrel is in sixteen parts, and not two parts as when a person holds the shaft of a spear. The interior of the barrel is rifled, the mechanical part of the rifling being formed by the spiral grooves on the rope which extend from one end of the rope to the other. A rope with three strands is usually used, and three spiral grooves are formed along the length of the rope and impress their shapes on the insides of the sixteen hands; and the spirals of the riflings are continuous through the sixteen hands. The barrel formed for the part of the rope held by the other team is similarly in sixteen parts, and

the rifling of the barrel of one team is continued regularly to the barrel of the other team.

The missile is represented by the tape, or handkerchief, tied to the middle of the rope, between the teams; and the object of each team is to throw the missile, or pull it, towards themselves over a line marked on the ground. But it may be that the middle portion of the rope, or perhaps all the rope, is really the missile, for the tape or handkerchief is used mainly to indicate the position of the middle of the rope. The rope, and tape also, move in a direction along the barrels, and the axis of the rope coincides with the axis of the barrels.

The rope, at each end, is passed over the shoulder and round the waist of the end man, and is hitched after the manner in which a bow string is hitched to the nock.

The actions of tug-of-war teams could be approximately represented if two compound crossbows were placed on a flat surface opposite each other with their stocks in the same line and butt ends touching; and the strings were joined by a cord drawn tightly. If a tape were placed at the middle of the cord, it would be slowly drawn towards the stronger crossbow; and the plates of each bow would pull on the cord in somewhat the same way as the arms of each team pull on the rope.

The arms of the members of a tug-of-war team pull together to throw the tape; and each pair of arms contributes its power as each plate of a Malabar or Chinese repeating crossbow contributes its power. The pull of one pair of arms is not made independently of the pulls made by the other pairs of arms of the team, but all pairs pull together at the same time. The power is obtained partly from the arms and partly from the weight of the men. The hands of each man are together on the rope, or nearly together, and therefore turning movements may be expected to occur, and they may be represented by the movements made when at a word of command the members suddenly turn round and face away from their opponents. The power is not applied evenly but in bursts or impulses, when the coach or captain

calls for a heave and then for another heave and so on. The force exerted by a team is not at its maximum immediately the tug-of-war begins, for a few moments are occupied in taking the strain. The force is at a maximum during one of the first heaves, for the men are then fresh. They gradually become tired, and the tension in the rope becomes less as the tug-of-war continues.

The author has some recollections of having read about some tests made by using a spring balance to discover the forces exerted in a tug-of-war rope. If expert teams were opposed and a spring balance were placed at the middle of the rope, or if a team were to pull a spring balance tied to a fixed point, the tensions in the rope at different times could be noticed, and information could then be obtained about the way the power is delivered. If, as has been suggested, there are relationships between the actions of a tug-of-war team and the arms of a compound crossbow, it should therefore be possible to know how a compound bow delivers its power, and therefore also how gunpowder or other explosive delivers its power to drive the bullet or shell along the barrel, because the principles of all types of offensive machines are the same. If therefore we can observe how the power is delivered by one type of the machine, we can know how it is delivered by any other type of machine. The tug-of-war machine delivers its power in such a way that it probably can be easily measured at any moment. It would seem the power of gunpowder therefore is not delivered uniformly but in bursts or impulses, which are most powerful soon after the bullet or shell begins to move, or conversely since actions can be reversed perhaps just before it reaches the muzzle. It would be difficult by direct observation to discover how a compound bow delivers its power, and still more difficult to discover how a gun delivers its power, for the delivery of the power is accomplished so rapidly. But the propelling movements of the tug-of-war machine are distorted so much that they take place very slowly and the way the power of the offensive machine is delivered can be studied at leisure.

The way the atom bomb delivers its power can also, if

the theory of this chapter is correct, be known by studying the way the tug-of-war machine delivers its power. Probably ways of discovering how pressures vary round an exploding atom bomb would be difficult to devise, except by the indirect ways indicated in this chapter.

It has always been a matter of surprise to most people that field athletic sports should for so many centuries have held the attention and attracted the studies of scholars and athletes. To most people they have appeared pointless and meaningless activities. The ancient Greeks devoted much attention and study to some of the sports like throwing the discus and throwing the javelin, but were unable to discover the secret of their fascination. Nobody today can give any rational explanation for their fascination. The human prototype theory however has lifted the veil and disclosed the secret of their meanings, and has shown they are activities of the utmost importance which merely need interpretation. One use of these sports, among many others, is to demonstrate how the offensive machine works. Each sport demonstrates some principle or principles that cannot be seen in any other type of the offensive machine. The tug-of-war, for example, shows how the offensive machine delivers its power, and we can at leisure study the methods of delivery. The caber machine shows how the barrel and missile can be distorted. The caber machine also helps to show how the power is delivered, and some things were said about this earlier in the work. When the study of the offensive machine is taken up by others, many of whom will be more qualified than the author for the task, we may expect great stores of new knowledge to be obtained.

PART II

THE

REPRODUCTIVE MACHINERY

Chapter 45

THE CLUB AND SPEAR

IT has been forced upon our notice that a mechanical weapon reproduces not only parts of the offensive machinery of the body, but also simultaneously reproduces parts of the reproductive machinery of the body. An attempt will now be made to discover how the reproductive machinery is mechanized by different weapons. But we are now about to begin to explore a vast field of research whose extent cannot be seen but which appears to be almost limitless; and it will not be possible for the author to do more than show how this field can be reached and explored. Fuller exploration will demand the efforts of a host of students, and probably of many generations of students.

According to Rule 12 the reproductive machinery of the body is mechanized simultaneously with the offensive machinery, and to the same degree. The first eleven Rules help to show how the offensive machinery is mechanized. Since the reproductive machinery is mechanized with the offensive machinery and to the same degree, it is likely that these Rules will apply also to the reproductive machinery, and that this is so will become apparent as the reproductive machinery is studied. But there are certain differences between the offensive and reproductive machines, which cause some difficulties in directly applying these Rules to the reproductive machinery. For example, a part of a mechanical weapon originates from its offensive counterpart, and is at first found near it. But the part of the weapon is seldom or never found near its human reproductive counterpart, and is usually far removed from it. But often it can be seen that transference has caused this separation of human and mechanical parts.

Clues for identifying corresponding parts of mechanical

weapons and parts of the reproductive machinery can often be obtained by studying the nomenclature of weapons; for, curiously, parts of weapons are more often named after parts of the reproductive machinery than after parts of the offensive machinery. Fortunately, also, very often when it is difficult to relate a part of a weapon to a part of the offensive machinery of the body it is easy to relate it to a part of the reproductive machinery. Thus, for example, it is not easy to discover the human prototype of the football, but as will presently be shown the part of the reproductive system to which the football corresponds can at once be known.

But no doubt the reader will be anxious, having been told of this new and vast field of research, to begin to explore it at once. We will therefore begin the study immediately, and point out general principles as we go along.

The first weapon we will study will be the club. This weapon has already been studied with reference to the offensive machinery; but now it will be studied with reference to the reproductive machinery, and many new facts about it will be discovered.

It has been shown that the typical club with a hitting part in the form of a roundish knob is a crude mechanical model or copy of a fist and arm; and the ways the fist and arm have been mechanized and reproduced artificially have been explained. Since the round knob and the handle reproduce the fist and arm quite recognizably, and the knob gives a blow after the manner the fist gives a blow, it seems strange that the knob or end of the club is not called the fist and the shaft the arm. Instead the knob is called the "head", and the shaft the "handle". At first this nomenclature is inexplicable. But, as mentioned above, nearly always, and perhaps always, when a part of a weapon is given a name corresponding to the name of a part of the body, the name refers to the part of the reproductive system represented by that part of the weapon. This is so often the case, that it is safe to say that the head of a club reproduces, very crudely and in a most elementary way, features of the part of the reproductive machinery contained in or formed by the head of the body.

If a club with a roundish head is placed upright, a curious circumstance can be noticed. Not only does it have a rudimentary resemblance to a fist and arm, it also somewhat resembles a head on a body; or since the handle is rather slender to represent the body, somewhat resembles a head on a spine or backbone, or skull on a backbone. This is because, besides being a mechanical reproduction of a fist and arm, it is also a mechanical reproduction of the part of the reproductive system contained in or formed by the head and body, or skull and backbone.

The reproductive system does not consist only of the genital organs, but ramifies all over the body. This is evident, say, because all parts of the body with their peculiarities are reproduced in the next generations. Also it is known that parts of the body like the head and neck and beard which are far removed from the genital organs are closely related to and affected by them; because, for example, if an animal is castrated, parts like the head and neck and beard are affected in shapes and in other ways. There need therefore be no surprise that the head and backbone are represented in the reproductive system and reproduced by parts of a weapon. It will become evident as the work proceeds that all parts of the body are connected to and form parts of the reproductive machinery, with perhaps one curious exception, this exception being the mammae or breasts.

The mammae are very evidently sexual organs, and one would think these organs would be prominently and commonly reproduced by weapons. But this does not seem to be the case, and to the author's knowledge these organs or glands are not represented on weapons. They are however beginning to be reproduced nowadays in mechanical forms by milking machines, the container into which the milk passes reproducing very clearly the udder of the cow, and the rubber tubes connected to the teats reproducing the teats, and the longer rubber tubes probably reproducing various tubes of the milk glands. The mammae or milk glands have only recently been reproduced mechanically; and until a few

years ago it would have seemed that no mechanical contrivances corresponded to these glands. Development of milking machines has not proceeded very far, but is likely to proceed farther in future, and correspondences between the parts of milking machines and parts of the mammae are therefore likely to increase and become more evident. A study of milking machines with reference to the body of a creature would probably reveal many of the secrets of the construction and actions of the milk glands, for necessarily each part and device of a milking machine is an extension of some part and device of the milk glands. This must be so or the mechanical and bodily mechanisms could not work together. But the author has no specialized knowledge of milking machines, and must leave this interesting field of research to his readers.

After this digression let us return to our study of the club. The name "handle" given to the shaft which supports the head of the club does not immediately provide a clue to identify it with a part of the reproductive machinery. But there is a part of the body called the handle, viz., the manubrium or handle of the breastbone. The breastbone will be studied later, and it will then be shown it is an extension of the backbone, and that therefore the handle of a club corresponds to the spine or backbone.

The skull and backbone are closely related, and there is some anatomical evidence to show that the skull is indeed an enlargement of one end of the backbone. The head of a club is often formed as an enlargement or swelling of the end of the handle; and the similarities of the relationships of the handle to the head of a club and of the backbone to the skull supports the belief that the handle corresponds to the backbone and the head of the club to the skull.

Now let us study the spear with reference to the reproductive machinery, and return later to the study of the club.

The shaft of a halberd, pike, thrusting spear, or similar type of weapon, is intimately related to the shaft contrivance formed by the wielder's backbone. This can be understood by studying the movements of the shaft and backbone, as

the weapon is being wielded. The shaft of the weapon is held approximately at right angles to the backbone. To elevate the shaft the wielder leans backwards and to depress it leans forwards, thus always keeping the shaft of the weapon and the shaft of the backbone as nearly as possible at right angles. The backbone also forms a kind of axis for the machine about which the weapon is turned to the right or left, and the angle through which the axis of the body turns is equal to the angle through which the weapon is turned. Thus, for example, if the wielder faces about and turns himself to meet an opponent at his back, the axis of the backbone is turned through two right angles and the shaft of the weapon similarly is turned through two right angles. The shaft of the weapon therefore is held always approximately at right angles to the backbone shaft, and the backbone shaft forms an axis round which the shaft of the weapon is turned. According to Rule 10 a mechanical part can be placed at right angles with respect to its human counterpart; and therefore since the shaft is held at right angles, approximately, to the backbone shaft, in all probability the mechanical shaft is an extension or copy of the backbone shaft turned through a right angle. In the offensive system, as has been explained, the shaft of the weapon is a mechanical counterpart of the arms of the wielder. In the reproductive system it is, so it now seems, a mechanical counterpart of the backbone shaft formed by the wielder.

The mechanical shaft reproduces only a few of the features of its human counterpart, and the two shafts differ in many respects. But although each type of spear shaft reproduces only a few of the features of the backbone shaft, yet between them the various types of spear shafts reproduce many of its features. Each type of spear shaft, as it were, specializes in reproducing features that are not reproduced or are not prominently reproduced by other types, as will now be shown.

1. The ordinary spear shaft is solid and not hollow: but the backbone has a hollow running nearly throughout its length. However, certain types of spears are hollow and

reproduce the hollow of the backbone. For example, tilting lances are often hollow; and bourdonasses are hollow. The modern military lance, when the shaft is of bamboo, is also hollow, although the hollow is not always continuous, the shaft being formed of various vertebrae-like segments, whose hollows may or may not be in communication with each other. The hollow spear shaft therefore reproduces the feature of the hollow of the backbone.

2. The ordinary spear shaft is in one piece: but the backbone consists of several pieces, or vertebrae, jointed or fastened together. The jointed shaft is however represented by the bamboo shaft of a lance; but still more closely by implements or tools like fishing rods and chimney sweeping rods. The parts of a bamboo shaft are not separate, and cannot move relatively to each other as the vertebrae can do. The joints or segments of a bamboo shaft therefore reproduce only certain features of the vertebrae. The joints or segments of a fishing rod or chimney sweeping rod however can be separated. Frequently the fishing rod or chimney sweeping rod is hollow, and therefore reproduces also the feature of the hollow of the backbone.

3. The backbone is a flexible contrivance and can bend: the ordinary spear shaft cannot bend. The backbone however does not possess a great degree of flexibility, and indeed certain of its vertebrae are fused with others and cannot bend relatively to each other. The degree of flexibility of the backbone is equalled by the degree of flexibility of the chimney sweeping rod, and often exceeded by that of the fishing rod and handle of the whip. It is also equalled by that of some types of spear shafts, notably by that of the assagai, which is made to vibrate and quiver by its wielder. Wood writes thus of this assagai:—

"When the Kaffir grasps his assagai, he and the weapon seem to become one being, the quivering spear seeming instinct with life imparted to it by its wielder . . . When thrown, the assagai does not lose this vibrating movement, but seems to vibrate stronger than before, the head describing a large arc of a circle, of which the balance point forms the centre . . .

"The whole look of an assagai in the air is very remarkable, and has never been properly represented. All illustrations have represented it as quite straight and stiff in its flight, whereas it looks just like a very slender serpent undulating itself gracefully through the air."[1]

The modern athletic javelin also vibrates and undulates as it moves through the air, and has some small degree of flexibility.

Although in man the shaft formed by the backbone is a flexible contrivance, in some creatures it becomes a permanently rigid contrivance, as in the tortoise, or a rigid contrivance on occasions, as in the blind-worm, a creature that looks like a snake. The tail of the blind-worm, when the creature is alarmed, becomes so stiff and brittle that a piece can be knocked off with a blow from a stick.

4. The butt of a spear is sometimes provided with a tuft of hair or other material, and a whip often ends in a thong with a lash at the end: but the human backbone does not end in a tuft or in a thong and lash. But in many creatures the backbone does end in a long tail and often is provided with a tuft at the end. The tail of a lion for example often ends in a tuft; and the spear shaft which ends in a tuft corresponds to and is probably meant to be a reproduction of the shaft formed by a lion's backbone and tail. Many types of weapons correspond more closely to parts of the bodies of creatures than to parts of the human body. This indeed is what might be expected, on the theory that weapons are extremely rudimentary and distorted copies of parts of the human body, and especially if as seems likely parts of the bodies of creatures are rudimentary and distorted copies of parts of the human body and related to corresponding parts of the human body in somewhat the same ways as parts of weapons are related to corresponding parts of the human body.

5. The shafts of some spears are much longer than the shaft formed by the human backbone. The shaft of a Fijian

[1] *The Natural History of Man.*

spear may be fifteen feet or more in length; and correspondence between the length of such a spear and the length of the human backbone is very remote. But, as stated above, parts of weapons often correspond more closely to parts of the bodies of creatures than they do to parts of the human body; and the backbone in some creatures is longer than any spear shaft can usefully be made. The backbone in the whale for example is longer than the shaft of any spear. It is possible that the limits of distortions of weapons are determined by the limits of distortions of corresponding contrivances in the bodies of creatures. The author is not prepared to state that this is so; but the subject is worth investigating, and the study might result in obtaining rules describing the ways in which distortions of weapons can occur.

6. The backbone has projecting spines along its length: but the spear shaft is usually smooth. But on many types of spears devices like spines project along the length of the weapon, often for a considerable distance from the point, and reproduce very clearly certain features of the spinous processes of the backbone. Usually these spines, or barbs, extend from the head. Often they are properly part of the head, but it seems fairly certain that on some types of spears they extend along the shaft. Occasionally a club has types of spines set along its length, which make the weapon seem to have vertebrae; but these also perhaps are usually properly parts of the head. A harpoon, which is a type of spear, sometimes has a barb, or spine, set on its shaft. For example, the harpoon arrow of the Andaman Islands, used for shooting pigs, has a barb set on its shaft. However, parts of the backbones of some creatures do not have spines, and are smooth. The end of the backbone of a frog, its urostyle, for example, has no spines, and is smooth.

It can now be understood that although no spear shaft reproduces more than a few features of the backbone shaft of a creature, yet many features are reproduced by different types of spear shafts or by the shafts of other weapons or implements. Each type of mechanical weapon or implement indeed seems to specialize in reproducing features of the

backbone of a creature which are less clearly or not at all reproduced by other types. Thus, the hollow spear reproduces prominently the neural canal or hollow of the spine; the assagai and whip and fishing rod reproduce its flexible properties.

It still remains to discover the human counterpart of the head or blade of the spear in the reproductive system. Nomenclature does not at once indicate the human counterpart, but with help from the Rules perhaps it can be discovered.

Figure 64 shows diagrammatically the backbone and certain connected parts. The skull or head is at the top of the backbone. The sacrum and coccyx are at the opposite end, and are formed by the lower end of the backbone, and together have a somewhat triangular shape when seen from the front or back.

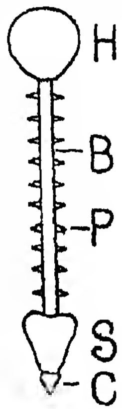


FIG. 64.

DIAGRAM OF BACKBONE

H, head;
B, backbone;
P, process;
S, sacrum;
C, coccyx.

The head and backbone, as we have seen, are reproduced by the typical club. The typical spear has a shaft which, it has been shown, reproduces the backbone. The head or blade of a spear is a continuation of the shaft and is at its end. It is never ball shaped, but often somewhat resembles a sacrum, or sacrum and coccyx; and possibly therefore the human prototype of the spear head in the reproductive system is the contrivance formed by the sacrum and coccyx. In the offensive system the head of the spear, as has been explained, reproduces the flat hand, either with fingers closed or opened.

The diagram thus represents a club and a spear. The backbone forms the shaft for the club and for the spear. In the diagram the spear is reversed compared with the club; and the head or blade of the spear is at the bottom of the shaft, and opposite the head of the club. The transference of the head of the spear to the

bottom of the shaft is however in accordance with Rule 8

The author cannot state definitely that the spear's head does reproduce the sacrum and coccyx contrivance. But further evidence that it does so can be given as follows:—

Many spears can be found intermediate in types between the broad bladed spear and the spear without a definite head. Somewhat similarly, some creatures have a broad sacrum, but in others the backbone is merely a type of straight shaft coming to a point at the end of the tail; and intermediate types can be found.

Again, the end of the handle opposite the head of a club often has a part which seems to reproduce the sacrum and coccyx. Two examples of clubs with this type of end are shown in *Figure 65.* The handles of some clubs taper to a point and they have no broad part at the lower end of the handle. Many types of clubs intermediate between those having a broad sacrum-like end and those whose handle tapers to a point can be found.

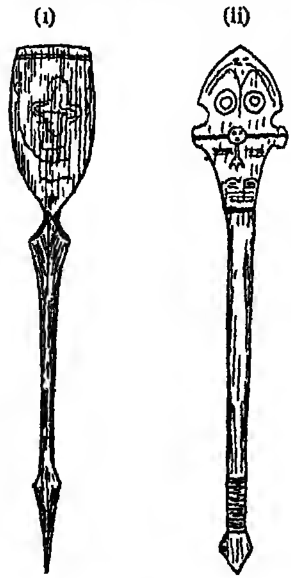


FIG. 65.
CLUBS,
SHOWING SKULLS
AND SACRUMS
(i) Guiana (ii) Samoa
J. G. Wood

Conversely, a spear often has a knob or other enlargement at its butt; and then reproduces the sacrum by means of its blade, and the human head by means of the knob or other enlargement of the butt. A darting spear which has a knob at its butt is of this type. The elephant spear whose butt is provided with a heavy block of wood at its butt to allow it to drop with force from a branch of a tree on to an elephant passing underneath is also of this type.

Thus it seems many types of clubs and spears reproduce both

the head and the sacrum, the head and sacrum being at opposite ends of the shaft.

The business end of the spear is often called the head. This can perhaps be explained by the circumstance that the head of the spear is reproduced in the reproductive system at the end of the backbone opposite the head of the creature, the head of the spear being in a transferred position (Rule 8), compared with the head of a club. But the broad business end of a spear is also often called the blade. This suggests that it corresponds to the blade-bone, or shoulder blade. But the author does not know if the blade-bone is closely related to the sacrum, or whether some types of spears reproduce the sacrum and others the blade-bone.

According to zoologists, "The bones of the trunk and head may be regarded as essentially composed of a series of bony rings or segments, arranged longitudinally. Anteriorly, these segments are much expanded and also much modified to form the bony case which encloses the brain and which is termed the cranium or skull."[2] It was observed earlier that the head of a club, when the club is made from a single piece of wood, is formed by the end of the handle swelling into a rounded knob or other enlargement. When the head is made separately from the handle, as for example when a stone is fastened by thongs to a wooden handle, the head is separated from but joined to the handle, in somewhat the same way as the skull is separated from but joined to the backbone. The thongs which join the stone to the handle correspond to the ligaments and other devices which join the skull to the backbone, and reproduce some of their features distantly.

Correspondence of materials of the handle of a club or spear to the materials of the backbone of a creature is remote when the handle is of wood; but is closer when the handle is made of bone. Handles of clubs are not often made of bone, but the handles of many implements are made of bone. Handles of adzes, for example, are often made of bone. The

[2] H. A. Nicholson, M.D., D.Sc., M.A., Ph.D., F.R.S.E., F.G.S., *Zoology*.

adze shown in Figure 15 has a handle of bone; and the handle reproduces the materials of a backbone fairly closely. The head of a creature is reproduced by the stone, but correspondence of materials of the skull and stone is poor. The thongs holding the stone to the handle reproduce in a crude and distant way the ligaments and other devices joining the head of a creature to its backbone.

One of the main theories of zoologists is that parts and devices of creatures like their backbones, skulls, spinous processes, and ligaments joining their skulls to their backbones, are related to and modified forms of corresponding parts and devices of the human body. It is now clear that parts and devices of weapons and other mechanical implements are also related to and modified forms of parts and devices of the human body, and also reproduce them but in much more rudimentary forms than they are reproduced by creatures.

The barb is not represented, to the author's knowledge, on the club, but is very often seen on the spear and on the arrow. The human prototype of the barb in the reproductive system can at once be known. According to the dictionary, the word barb is derived from the Latin *barba*, the beard. Most spears and arrows have a double barb, when they are barbed; but on some the barb is single, or on only one side of the shaft or head. If a weapon with a single barb is examined, the reason for the name barb, or beard, of this appendage of the head of the weapon is apparent; for a barb on the head of a spear or an arrow resembles the beard on the head of a man. The head of the weapon reproduces in a diminutive form the head of the wielder, and the barb depends from it much as the beard depends from the human head or face.

The barb is usually formed on both sides of the head of the weapon. Frequently, and especially on spears, the device is distorted so that a considerable number of barbs are fitted. For example, an African spear, used for thrusting down the throat of a captured chief, is made with a series of barbs for a considerable length from the point, some pointing

backwards and some forwards, so as to make it impossible to be withdrawn.[3]

The beard is a prominent sexual feature, and obviously connected to a part of the reproductive machinery; and it is therefore to be expected that it will be prominently and commonly represented on weapons. Only a few features of the beard are reproduced by the barb of a spear or of an arrow. Other features of the beard however are reproduced by the feathers of an arrow, as will be explained later in the chapter on the bow and crossbow.

[3] The Rev. J. G. Wood, M.A., F.L.S., etc., *The Natural History of Man.*

CHAPTER 46

GAMES IMPLEMENTS

MANY parts of the human reproductive machinery are reproduced by parts of weapons or implements used in games. Often the parts reproduced can at once be known from their names.

Several parts of the reproductive machinery are reproduced by the tennis racket, and the parts reproduced can be known from the names given to parts of the racket. The hitting part of the lawn tennis racket is called the head, and the part within the frame the face. The part of the racket where head and handle meet is called the throat; and the lower parts of the frame extending from the throat to about one half or one third of the way round the frame are called the shoulders. The extension of the wielder's arm is called the handle or stem.

If the racket is placed upright, it can be seen that the parts mentioned above are in the same relative positions to each other as corresponding parts of the body; and that the racket has a rudimentary resemblance to a head, face, throat, and shoulders, above a body or backbone formed by the handle or stem. The parts of the reproductive machinery reproduced by a lawn tennis racket are therefore the head, face, shoulders, throat, and backbone. The frame of the racket reproduces the frame of the head.

The parts of the racket have been so named because they do have some resemblances in shapes and actions to the shapes and actions of the parts of the body after which they are called, and because they are in the same positions relatively to each other as corresponding parts of the body. This method of naming parts might be regarded as fanciful and without significance. This view could be maintained if only

a few implements received names corresponding to names of parts of the body; but since it is almost the universal practice, among civilized and uncivilized peoples, to name parts of weapons, instruments, and machines, after parts of the body, this view becomes untenable, and can be shown to be wrong now that it has been shown there are deep and sufficient reasons for the nearly universal use of this type of nomenclature. Further, it will be seen that when, as is often the case, there is a double system of nomenclature for weapons, one system then refers to the offensive machinery and the other to the reproductive machinery. This cannot be the result of chance or coincidence.

When the shaft of a lawn tennis or badminton racket is made of steel and bifurcates, the throat of the racket reproduces the two tubes of the throat, the wind-pipe and gullet. In the offensive system, it has been explained, these two tubes or rods correspond to the two bones of the forearm, the radius and the ulna.

The nomenclature of the golf club is at first confusing, because two different systems are used. In one, names corresponding to the upper parts of the body are used, in the other names corresponding to the lower parts. Since, as has been said, the part of the club below the shaft corresponds to the foot, it seems reasonable that one part of it should be called the "toe", another the "heel", and the bottom the "sole". But the hitting part is called

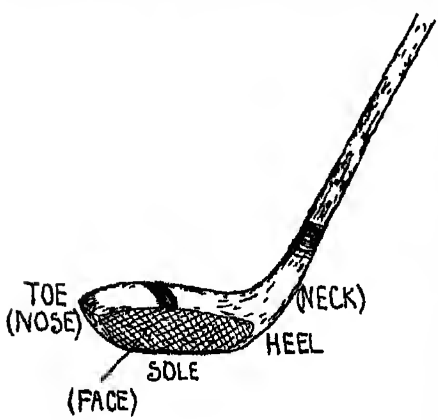


FIG. 66. HEAD OF A GOLF CLUB

Names without brackets refer to the offensive machinery.

Names within brackets refer to the reproductive machinery.

also the head,* and its plane surface the face, the part corresponding to the toe in the other system is called the nose in this system, and the bent or crooked part of the club where the shaft joins the head is called the neck. Now since the head, face, nose, and neck of the player never come into contact with or come very near the hitting part of the club, probably the second system of nomenclature refers to the parts of the reproductive machine reproduced by the club, which therefore reproduces certain features of the head, face, nose, neck, and backbone, the shaft reproducing the backbone. The club at times is fairly close to or alongside the leg and foot; and perhaps the names toe, heel, and sole refer to the parts of the offensive machine reproduced. A golf club placed with its hitting end upwards obviously reproduces the outline of the head and backbone with the nose and face and neck as well. Placed with the hitting end downwards it also somewhat resembles the shaft of a leg, with the toe, heel, and sole reproduced distantly but distinctly as well.

The head and face are thus reproduced by more than one type of weapon or implement, since for example the lawn tennis racket and golf club both reproduce these parts. They are however differently reproduced by the different weapons. The lawn tennis racket reproduces the head merely as a flat oval—a kind of front view: the golf club reproduces more its solid form. The face is also differently reproduced by the racket and the club. This is probably because each type of implement is developing to reproduce certain features or aspects of the reproductive machine that the other does not so well reproduce, each specializing as it were in reproducing particular peculiarities or aspects. Both implements reproduce the spine, but in different ways. It should be noticed the golf club does not reproduce the throat or the shoulders, for no part of the club is called the throat or the shoulder: and the lawn tennis racket does not reproduce

* *The Badminton Library*, Volume "Golf," in its Glossary of Terms defines the head of a club as follows:— "This word is a striking specimen of incongruity and mixed metaphor. A head is the *lowest* part of a club, and possesses, among other mysterious characteristics, a *sole*, a *heel*, a *toe*, or *nose*, a *neck*, and a *face!*"

the neck or nose, nor does it reproduce any features of the foot, and is apparently not directly related to the leg and foot, as is evident also since it is not placed alongside the leg and foot. Neither implement reproduces the barb or beard or blade.

The part of the reproductive machinery represented by the football can at once be known from the fact that the inner part of it is called the bladder. Strutt, describing the football of his day, writes: "The ball was commonly made of a blown bladder, and cased with leather." The inner part of the ball is therefore undoubtedly derived from the bladder, but is not directly derived from the human bladder but from that of an animal. An animal's bladder however has most of the essential features of the human bladder, and can represent it very closely. The leather case serves to stiffen and protect the bladder, and evidently corresponds to the muscular coverings of a creature's bladder.

It is said by some authorities that the Rugby football is oval in shape because it preserves the shape of an animal's bladder, more or less. Thus one writer says, "The original football . . . was a bladder . . . As bladders are not round, but oblong, we at once have the origin of the oblate Rugby Union ball." The writer goes on to say that it is incorrect to think the Rugby football is made oval merely for the convenience of carrying it.[1] The spherical Association football and the ellipsoidal Rugby football are developing in different ways; and are specializing to reproduce different parts or features of the bladder. But it is difficult from a study of such very rudimentary models of human parts to know how they are specializing. According to the Encyclopaedia Britannica, the human bladder is seldom distended so as to hold more than about 10 ounces.[2] If the capacity of the average person's bladder is taken as 10 ounces, a simple arithmetical calculation shows that the Association football of maximum size allowed at present by the rules of

[1] E. T. Sachs, Article Football, in *Outdoor Games and Recreations.*

[2] Article, Urinary System.

the game, that is one having a circumference of 28 inches, has a capacity or volume very nearly 22 times that of the human bladder. This suggests the football bladder is a combined contrivance representing all the bladders of the 22 players in the game. The Rugby football is of slightly larger capacity; but there is not the same close correspondence between the capacities of the bladders of the 30 players and the capacity of the ball, as is the case with the Association football and the 22 players. Possibly this is because the Rugby football is being developed to reproduce the shape, but the Association football the capacity of the bladder. These statements however should not be regarded as certain, but as little more than speculations.

When an animal's bladder was used, the two ureters, or tubes which lead the urine from the kidneys to the bladder, were very faithfully reproduced, at least for small portions of their lengths; and the urethra, or tube which leads the urine away to an opening of the body, was also faithfully reproduced; because portions of these tubes were retained and formed the openings by which air was blown into and let out of the bladder. These three tubes are represented in the modern football by the single tube through which air is pumped into and let out of the bladder.

The tube of the modern football bladder combines into one device the three tubes of the old time football bladder, and one tube now represents the three tubes of the human bladder. It can be noticed that some creatures have tubes which in other creatures are combined into one tube, or yet again in others are represented by a greater number of tubes. Thus, in most creatures food is taken in through a mouth and waste material is ejected through an anus; but in many creatures, the sea-anemone for example, waste material is ejected through the opening through which food is taken in; and the mouth and anus are represented by a single tube or opening. Or again, in the frog the excrement, urine, and spermatozoa, are all discharged through a common aperture; but in man the excrement and urine are discharged through separate openings of the body.

It might be thought that because formerly the bladder was taken from an animal but is now merely an artificial one of rubber that the course of development of the football bladder is away from and not towards closer correspondence to the bladder of the player. But this is not so, because the bladder taken from an animal when placed in the football is dead, and the course of development is to try and reproduce features of the live bladder. It is impossible to resuscitate a dead bladder; and the only method of eventually making a live bladder is to start ab initio, by trying to reproduce at first merely one or two of its features with some sort of accuracy, as for example its shape or capacity or materials. Nature cannot be copied directly, and in order to copy nature's contrivances man must first decompose them, and then try to rearrange them. Thus, until recently man has always used the limb of a tree or the bone of an animal as an extension of his arm when making say a club or adze handle. But he has now become more content to give his arm an extension say by using a steel shaft; and nowadays golf club shafts and lawn tennis racket handles are frequently made of steel. Or as another example, man has for ages tried to reproduce the skin of the foot by making a boot or shoe of leather; but is now starting less ambitiously by using synthetic materials like rubber. The use of synthetic materials does not therefore signify that man is developing his materials away from closer correspondence to the materials of nature. It could be said that until recently nature lent man materials because he was incapable of making his own, but that now she is beginning to force him to make his own. By composing his own materials, he will in time learn the secrets of nature's materials.

The tube of the modern football bladder is sealed to prevent the escape of air, by being bent over on itself, and then being bound with twine or string to keep it bent. The method of bending the tube over on itself reproduces distantly the method by which the fluid in the human bladder is prevented from returning to the kidneys; for the bladder as it fills compresses the ureter tubes against themselves and thus seals

them, the action having some resemblances to the action of a valve. The valve of the pallone ball acts somewhat on this principle. The way to make the pallone valve has been thus described by Dr. A. L. Fisher:—

"Take three round pieces of the hide of which the ball is composed, each the size of a halfpenny; punch a small hole in the middle of two of them, and leave the third entire. Place them one over the other, the two perforated ones being uppermost. Then sew them all together by the stitch used to unite the leather thongs which compose the trace of a carriage harness. This seam must be at a quarter of an inch from the edge, and should only comprise three quarters of the circumference, the last quarter being left intact. This done, and two pieces of hide of the inner and outer coat to which the valve is to be fixed having been selected, punch a hole through the middle of each, then sew in the round pieces with the holes corresponding to those in the coats. By this arrangement, when the parts composing the ball have been put together, if the air be pumped into the ball from without, after passing through the four holes, it will, on arriving at the unperforated third piece, be diverted laterally into the cavity of the ball, and this same entire piece, being pushed forcibly outwards by the pressure of the air from within, will stop the holes in the two perforated pieces, and prevent the escape of air from the interior of the ball."

A study of the action of the pallone valve shows that air is prevented from escaping in almost the same way as the urine is prevented from escaping back through the ureter tubes to the kidneys. In the ball the pressure of the air causes the leather of the unperforated piece to be pressed against a perforated piece, thus sealing the opening. The ureters enter the bladder obliquely so that the muscle of the bladder wall nips them when the bladder contracts and so prevents the urine flowing back to the kidneys. The urine can then escape only through the third tube, the urethra.

There is some correspondence between the length of the tube of the modern football bladder and the length of the human urethra tube. Correspondence is fairly close in the

case of the female urethra, which is about $1\frac{1}{2}$ inches long; but less close in the case of the male tube, which is about 8 inches long.

To seal the bladder of the modern football, the person who has pumped the air in must bend the tube over on itself and then bind it with string or with a rubber band or other material. But the person who pumps air into the pallone ball does not directly have to seal the valve, because the pressure of the air within the ball seals it. Indirectly of course he does seal it, because the valve is sealed through the pressure of air caused by his pumping actions. The valve of the modern football is therefore sealed with a conscious action, but the valve of the pallone ball with an unconscious action, the mechanisms of the pallone valve working however in sympathy with the actions of the pumper.

The pallone ball does not consist of a bladder and a leather case, but has merely two cases; and may be said to have no bladder, although since the inner case is air tight it acts somewhat like a bladder. The inner case, however, probably is not strictly a bladder, and the two cases reproduce merely the muscular coats or casings of the bladder of a creature, as is evident from the materials of the cases which reproduce fairly well the materials of the muscular cases of the bladder of a creature but do not reproduce those of the bladder itself. Dr. A. L. Fisher's description of the ball is as follows: —

"The Pallone as used in Italy at the present day (1871), is a heavy ball of five inches in diameter, made of two coats of cowhide inflated with air. This cowhide has simply been divested of its hair by steeping in lime water, without having undergone any part of the process of tanning. In this state it is of a dead white colour, exceedingly soft and flexible, and remarkably tough. The inner coat of the ball is composed of four pieces of hide of a lozenge form, which when sewn together form an irregular sphere. The outer coat is composed of eight triangular pieces, which for greater accuracy are cut out with a triangular punch, of which the three sides are slightly convex. These eight pieces, when sewn together,

present on inflation a perfect sphere . . . The sewing of the ball is an operation of great importance . . for everything in the game depends upon the ball being perfectly air tight. Independent of the careful sewing this end is ensured by steeping the ball afterwards in water, which causes the hemp to swell and close the holes made by the stitches . . . When a Pallone is properly inflated, it ought to weigh twelve ounces, and such is the degree of elasticity imparted to it by the highly compressed state of the air, that if it fall from a height it will rebound within a few inches, to the point from which it fell."

If we are correct in thinking the pallone does not reproduce the bladder and reproduces merely the muscular coats of the bladder, perhaps an explanation can be given for Dr. Fisher's failure to provide it with a bladder. In his interesting and valuable treatise he describes at some length his attempts to make a pallone ball with a bladder of rubber and only one coat of leather or hide. He interested an English rubber manufacturer in the project; but the attempts ended in failure; and it seems Dr. Fisher was trying to force development of the pallone ball along different lines, to possess characteristics of the bladder as well as of the outer muscular coats, whereas it seems the pallone ball is essentially a reproduction of the muscular coats only and should not reproduce the bladder also. Whether pallone players would have accepted and used a ball with a bladder, if Dr. Fisher had been successful in his project, cannot be known.

The Association football, the Rugby football, and the pallone ball, it is clear are being developed to reproduce different features of the bladder. Possibly the Association football reproduces or preserves especially the capacity of the mechanical bladder in relation to the capacity of the human bladder; and the Rugby football the shape of the mechanical bladder in relation to the shape of the human bladder. The Association football and the Rugby football both reproduce the feature of the bladder encased by a muscular covering or coat. The human bladder however has a covering of several coats. The Association and Rugby footballs reproduce only

one coat by means of the leather case. The feature of several casings or coats is however reproduced by the pallone ball which has two coats, and curiously no bladder. It might be said the makers of the Association football leave the business of reproducing the shape of the bladder to the makers of the Rugby football, who leave the matter of the relationships of the volumes of the ball and human bladder to the makers of the Association football. The makers of the pallone ball specialize in reproducing the muscular coats of the bladder, and also the feature of the automatic valve device of the ureters, and leave the business of reproducing features of the bladder almost entirely to the makers of the Association and Rugby footballs. This tendency to specialize in reproducing certain features only of parts of the body and of makers of mechanical contrivances of avoiding trespassing on the preserves of makers of other types of mechanical contrivances can be noticed over the whole field of mechanical production. It is encouraged and enforced sometimes by the taking out of patents; but is as strongly marked among makers of primitive implements like clubs, spears, and bows and arrows. A study of this phenomenon would show there is law and order in discovery and development of mechanical contrivances. This interesting field of study however is a vast one, and is another one which must be left to the author's readers.

The makers of the pallone ball also seem to specialize and to have a monopoly in reproducing the appearance and texture of the human skin in the material of the ball, as can be understood from the following note which Dr. Fisher gives about the resemblance of the skin of the ball to the human skin:—

"When I was experimenting on the manufacture of the Pallone Balls in the year 1852, a skilful workman whom I had employed, after working on them for two or three days, suddenly conceived the idea that they were made of *human skin*, and refused to have anything further to do with them. Certainly the resemblance between the two was very striking."

Other types of the hollow ball are the lawn tennis ball and table tennis ball; and there are also many other types. All seem to reproduce the bladder in different ways; but the author has not discovered the particular features of the bladder reproduced by these other balls.

Three other main types of balls can be distinguished. The first of these is the solid ball, represented by such balls as the croquet ball, billiard ball, sling stone, and musket ball. None of these reproduces the bladder, for none of them has a hollow cavity which is a main feature of balls reproducing the bladder. The billiard ball, sling stone, and musket ball probably reproduce features of the testis, each reproducing certain of its features. The oval sling stone reproduces especially the shape and size of the testis. The scrotum is reproduced by the leather pouch of the sling in which the stone is placed and contained. The billiard ball does not reproduce the shape of the testis so well. The scrotum is reproduced in a very distorted form by the billiard table pocket. The croquet ball and bowl seem too large to be reproducing the testis; but the author does not know if some other part of the reproductive system is reproduced by these large solid balls.

The next type is the stuffed ball, represented by the old tennis ball and old golf ball and old stoolball and the modern cricket ball. These perhaps reproduce the testis and scrotum, the inner part or core representing the testis and the cover the scrotum.

The last type is the ball with a covering of rubber or other material, whose inner part is formed mainly by long lengths or strips of materials, usually rubber, coiled or wound into a ball. This type is represented by the golf ball which certainly reproduces the testis and the scrotum. The structure of the core of the golf ball corresponds with fair fidelity to the structure of the testis. The testis is formed by a mass of much coiled tubes or tubules; and it has been estimated that the total length of the seminiferous tubes in the two glands is little short of a mile.[3] The golf ball's core is not

[3] *Encyclopaedia Britannica*, Reproductive System.

made of rubber tubes, but from flat rubber strips, which nowadays are often almost shreds, but the total length of the strips does not equal the total length of the tubes of the testes; but correspondence of structures is unmistakable. The golf ball does not reproduce the oval shape of the testis. It therefore reproduces the interior structure of the testis fairly well, but its shape only poorly. The scrotum is reproduced rather poorly by the hard rubber covering of the ball. The ball used in a Belgian variety of golf played towards the end of the last century did reproduce the shape of the testis fairly well, for it was "egg-shaped."[4] It was a solid wooden ball and did not reproduce the interior structure of the testis as well as it is reproduced by the modern golf ball.

[4] *The Badminton Library*, Golf.

CHAPTER 47

THE SWORD AND SHIELD

MUCH help can be obtained from nomenclature in discovering the human counterparts of the sword or dagger in the reproductive system. *Figure 67* shows diagrammatically the breastbone or sternum. Its parts have popular names and also scientific names. The scientific names have been given because of resemblances of the breastbone to a sword or dagger. The breastbone does not much resemble a modern sword, but has a close resemblance to some swords used in classical times.

The upper part of the breastbone is called the manubrium, the latin word manubrium being equivalent to handle. The middle portion is called the gladiolus, a word related to the Latin word gladius, a sword. The point or end is called the xiphoid bone or the xiphisternum, from the Greek word xiphos, a sword. It is also called the ensiform cartilage, from the Latin words ensis, a sword and especially a Gaulish broadsword, and forma, form.

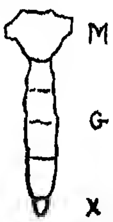


FIG. 67.
DIAGRAM OF BREASTBONE
M, manubrium;
G, gladiolus;
X, xiphisternum.

The common or popular names for parts of weapons nearly always provide reliable clues for identifying parts of the body to which the parts of the weapons correspond. Unless it is maintained that scientific nomenclature is merely fanciful, it is to be expected that it will similarly provide clues for identifying the parts of the body to which parts of weapons or other implements correspond. Scientific nomenclature is probably fairly reliable, provided it has stood the test of long usage and general acceptance, a test also of the accuracy of any system of nomenclature. The scientific names given to the

parts of the breastbone have passed this test, and therefore in all probability point unerringly to the parts of the body to which parts of the sword or dagger correspond.

The breastbone is approximately parallel to the backbone, and connected to it by the rib bones, the breastbone and backbone being at opposite ends of these bones. If Rule 8, which says that parts of the offensive machine can be transferred to opposite ends of other parts with which they are in contact, holds good also for the reproductive machine, it is evident the breastbone is a counterpart or modified copy of part of the backbone transferred to the ends of the ribs opposite the backbone. Hence, if parts of a sword correspond to parts of the breastbone, they correspond also to parts of the backbone. That is, the sword is derived directly from the breastbone and indirectly from the backbone, and corresponds to both these human contrivances.

The breastbone is a modified counterpart probably of only the parts of the backbone to which it is joined by ribs, because no other parts of the backbone are transferred across or along bones to the breastbone. If this is correct, the breastbone is a counterpart of only those parts of the backbone between the highest rib and the lowest rib which join the backbone to the breastbone, that is it is a counterpart of only the upper ten thoracic vertebrae.

In some creatures a breastbone is not reproduced. Thus, a snake has no breastbone, and no parts of the backbone are transferred across the ribs to form a breastbone. The breastbone in some creatures is not a rigid contrivance, but is in several separate but jointed parts. That of the rabbit, for example, consists of seven bones, called sternebrae. Counterparts of the backbone are transferred as a rigid contrivance in many creatures. In the tortoise, they help to form the solid plate, or plastron, under the body. In birds, the sternum is developed into a large boat shaped contrivance, with a developed keel, which is a prototype of the keel of a boat, as its name reveals and as a study of nautical implements and contrivances would soon show.

A study of the structure of a tortoise helps to reveal the

prototypes of parts of certain types of shields. Parts of some weapons, offensive and defensive, and other mechanical implements, as has been said, correspond more closely to parts of the bodies of creatures than they do to parts of the human body. A Zulu shield reproduces very closely certain features of the body of a tortoise. Its dimensions, however, are determined by the dimensions of its wielder.

The Zulu shield under discussion is shown in *Figure 68.* A backbone is formed by the long stick or shaft; a head by the knob at the top. Spinous or transverse processes of the backbone are represented by the dark lines at the sides of the shaft, which are formed by slits in the hide of the shield. Thongs are passed through some of these to hold the shaft and the skin of the shield together. The lower end of the shaft ends in a point, so that when the warrior is tired of carrying the shield, he can stand it upright in the ground.

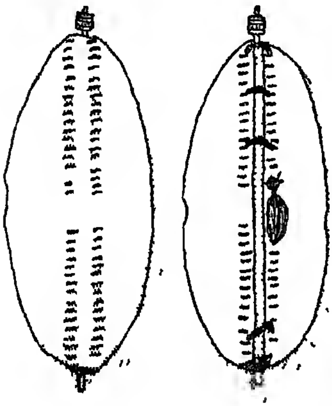


FIG. 68.
ZULU WAR SHIELD
J. G. Wood

The width of the shield is about the width of the body. When placed upright, according to Wood "the shield ought to be just so tall that when the owner stands erect, his eyes can just look over the top of the shield, while the end of the stick reaches to the crown of his head . . . the upper end of the stick has an ornament upon it. This is made of the furry skin of some animal, which is cut into strips . . . and the strips are wound upon the stick in a drum-like shape." Since it is a rule that mechanical parts are always placed or held as near their human counterparts as possible, the human counterparts of the parts of this shield can easily be known. The furry knob at the top is opposite the wielder's

head, and is evidently a crude representation of it; but reproduces it very poorly as regards materials and shape. The shaft or pole reproduces the wielder's backbone; and the black marks or slits represent transverse processes of the spine. The oval ox-hide represents the skin of the wielder's body, and is an artificial extension of it, serving the useful purpose of directly receiving the thrusts of the opponent's weapons, which otherwise might have to be received directly by the wielder's skin. The part of the shaft below the shield is an artificial reproduction of the contrivance formed by the wielder's legs. That this is so is shown by the fact that when being used the shield is supported by the human legs, but by the mechanical leg device when it is "used as a rest, on which the shield can stand whenever the owner is tired of carrying it." The human leg contrivance is formed by two legs; but in the shield the reproduction of the human legs is fused into a single contrivance as the lower part of the shaft or pole.

The Zulu shield also fairly closely reproduces certain features of a tortoise's body. In the tortoise the backbone is fused to the shield, or carapace, and the backbone and carapace become a single contrivance; which is fairly well reproduced by this Zulu shield. The tail of the tortoise, or rather the skeleton of its tail, is represented by the lower part of the shaft which projects beyond the oval hide. The tortoise's shield serves as a protection and guard against its enemies; and both shields are therefore used for similar purposes.

In some varieties of the Zulu shield, the ox-hide instead of being oval has a very pronounced waist, giving it the shape of an hour-glass, the waist of the shield corresponding in shape and height to the waist of the wielder. In the shield shown in the illustration, the waist is indicated by the two small indentations at the sides of the oval of the ox-hide. As the waist becomes more developed, correspondence of the shape of the shield to the shape of the carapace of a tortoise becomes less evident but becomes correspondingly more close to that of the outline of the human body. A shield with a

very pronounced waist perhaps reproduces more closely the separate thorax and abdomen of insects, which have wasp-waists.

Chapter 48

THE BOW AND CROSSBOW

THE shaft of an arrow in the offensive system, it has been shown, forms an extension of the right arm of the archer; the head of the arrow an extension of the fist or of one of the knuckles; the barb an extension of the device formed by a bent finger; and the feathers an extension of the rifling devices of the fingers.

The human counterparts of the bow and arrow in the reproductive system are much easier to discover; and most of them can at once be known by inspection. Thus, if a bow and arrow is held so that the butt of the arrow is lowest and its head uppermost, the outline of the human body with arms outstretched can be distantly seen. The shaft then reproduces the backbone or spine; the head of the arrow reproduces the head of the archer, as the name "head" shows; and the barb reproduces certain features of the beard. The feathers as will soon be explained also reproduce features of the beard; but they are in transferred positions and are at the bottom of the spine, or shaft, of the arrow instead of at the head. Probably, but the author is not certain of this, the bow strings reproduce features of the spinal cord, the spinal cord being turned through a right angle compared with the spine, represented by the shaft of the arrow.

The barb is usually made of metal or flint or bone or other hard material, and does not reproduce very well either the materials of the beard or the number of its component parts, or hairs; and may be said to reproduce merely the shape of a beard. The barb is not in a transferred position compared with the head of the arrow, for its depends or hangs from the head, but compared with the wielder's beard it is of course in a transferred position.

Several characteristics of the beard, which are not represented by the barb at the head of the arrow, are represented by the barbs at the butt, formed by the barbs of the feathers. A feather has a considerable number of barbs, each set on the butt of the arrow in much the same way as the barb at the fore part is set on the arrow's head. Each barb of the feather is set on the butt at an angle and inclined backwards; and as it depends from the butt has a rudimentary resemblance to a hair of a beard depending from a face. Since the vane of a feather is formed by a great many barbs, there is therefore probably sometimes a fairly close correspondence between the number of hairs, or barbs, on an arrow and the number of hairs or barbs on the wielder's face. Also, along the length of each barb of the feather, there are numbers of barbules, or little barbs or beards, which serve to hold the barbs to each other and make a plane surface for the feather.

The barbs and feathers of an arrow besides reproducing features of the beard reproduce also features of the vertebrae of the backbone. If a section is taken through the butt of a feathered arrow, at right angles to its axis, the three spinous processes of the human backbone will be represented by the sections of the three feathers. Three spines project from a human vertebra, one a spinous process at the back, and the other two transverse processes from the sides of the vertebra. A section through the butt of an arrow may show only two spinous processes, or only one, or four, or none at all if the arrow is not feathered, the number of processes depending on the number of feathers on the butt. When more or less than three spinous processes are shown by the section, correspondence of the spines to those of man becomes less evident than to those of some creatures.

In man the spines are not evenly spaced round the backbone, for, as has been said, one spine projects towards the back and the other two project towards the sides of the body, and there is no process towards the front of the body. The spines on an arrow are usually evenly spaced; but on a cross-bow bolt with three feathers, the feathers are spaced more

after the manner of the human spines; because the bolt cannot be feathered underneath, where it lies on the barrel; and one feather is therefore placed on the top and the other two feathers are placed at the sides of the bolt. A section of such a bolt would therefore show the spinous processes spaced much as along the human backbone. Sometimes a bolt has four feathers. No feather is placed below the bolt, and all four are then spaced round the butt at the sides and top. In different creatures there are somewhat similar variations in the number of spines and in their positions.

A section through the main part of the shaft of an arrow or bolt does not show any projecting spines. Spinous processes somewhat similarly are not present on some parts of the backbones of some creatures. For example, the end of the frog's backbone is smooth and has no spines projecting from it.

A section of a barbed head at right angles to the axis of the shaft usually shows two spines, since the head usually has two barbs. But if the barb is single, the section shows only one spine. If the barb is triple, it shows three spines.

As has been pointed out, when the arrow is laid on the bow the weapon reproduces certain features of the human body. The human head is represented by the head of the arrow, the arms by the bow arms, and the spine by the shaft of the arrow; and the shaft reproduces several features of the backbone or spine. The shaft, it will now be shown, also reproduces, in rudimentary forms, features of the body cavity.

Sometimes the shaft of an arrow is made of the entire limb of a tree or plant, or limb from which the bark or skin has not been removed. An arrow made from a bamboo cane or a reed, for example, is entire, and still retains all the parts and devices of the limb, and also retains its skin. The bark or skin of such an arrow therefore represents the skin of the trunk of the body, or skin of the body cavity, and reproduces the human skin in a rudimentary mechanical or artificial form.

Before it was cut from the rest of the plant, the bamboo or

reed shaft was "alive"; and was provided with channels through which food and water passed between the roots and leaves, the food and water passing through the shaft probably in ways that had some resemblances to the ways in which food and water are transported in the body between different parts of the body. When cut from the rest of the plant, food and water ceased to circulate in the channels of the shaft; but the structures which formerly allowed for this circulation still remained very little changed. Therefore if, as seems likely, the structure of a plant is related to the structure of a creature, the structure of the shaft of the arrow reproduces in a rudimentary way the structure of the cavity of the body. That is, the shaft reproduces artificially in an undeveloped form certain structures of the body of a creature, like the alimentary or food canal, the blood and water circulatory systems, and the skeleton of the body.

The shaft of an arrow or a club or a spear however is not always entire, for it is often artificially shaped, and in the process of shaping it the bark or skin and much of the structure of the wood may be removed. But when this is done, often the core of the wood is left; and the hard core may be part of the heart-wood, which is the central part of the wood where the cells have died. The heart-wood, or duramen, is called the spine of the wood. The fact that it is called the spine confirms the belief that the shaft corresponds to the spine, and that when the shaft is entire, the skeleton of a creature is represented in the structure of the wood.

Features of the body cavity are also reproduced by the bow arms. The convex or outer side of a bow is called the back and the concave or inner side the belly. These names do not show how the bow arms are related to the offensive machinery; but probably refer to the parts of the reproductive machinery reproduced by the bow arms. If this is correct, then the bow arms also reproduce the body cavity with its various contrivances, and the belly of the bow corresponds to the belly of the body, and the back of the bow corresponds to the back of the body. The bow arms are at right angles to the shaft of the arrow where they meet the

shaft, and therefore the parts and devices of the body cavity reproduced by the bow arms have been turned through a right angle compared with similar parts and devices reproduced by the shaft of the arrow. As has been explained, a composite bow reproduces very evidently features of the structure of a limb.

When an archer holds a spare arrow in his left hand, its shaft lies against and parallel to the bow stave; and the feature of the spine or backbone lying parallel to and near the body cavity is then reproduced.

The handle of a carriage whip reproduces, as has been shown, features of the backbone, and also features of the crop of a creature. Therefore it seems it also reproduces several features of the cavity of the body.

According to Sir Ralph Payne-Gallwey, "every inch of a Turkish bow or arrow was named in a manner that could be recognized or referred to."[1] Unfortunately he mentions the names of only three parts. The enlarged centre of the arrow is called the "stomach"; from the centre to the point, the "trousers"; from the centre to the nock, the "neck". It is unlikely that the names are merely fanciful; and probably they point unerringly to parts of the body or to coverings or clothes represented by the parts of the Turkish arrow. Since the enlarged centre of the arrow is called the stomach, further evidence is provided to show features of the cavity of the body are reproduced by the shaft of an arrow.

The spine is reproduced in the crossbow machine by the bolt or arrow lying on the top of the stock; and the body cavity with its various parts and devices is reproduced by the wooden stock which lies below and supports the spine.

A section through the stock and barrel and arrow of a crossbow, at right angles to the axis of the barrel, is shown diagrammatically in *Figure 69*.

The larger circle shows the section of the wood of the stock. Through this section, during the life of the wood, food and water and other substances passed between the roots and leaves; and its structure therefore probably reproduces

[1] *The Crossbow*.

some features of the body cavity of a creature. The smaller circle is the section of the arrow, with spinous processes formed by the feathers or barbs emerging from its sides. The arrow reproduces the spine, and the feathers reproduce the processes which emerge from a vertebra of the spine of a creature. The thick semi-circle shows the section of the barrel. This evidently reproduces the neural arches, or parts of the backbone which, in the human body meet again and form the neural or spinal column which encloses the spinal cord. The neural arch becomes fully developed in the gun machine, and is represented by the barrel; and the arrow disappears and is represented by the bullet. The spinous processes become represented by the riflings on the barrel. Since the semi-circular neural arch of the crossbow becomes the circular arch of the gun, and the arrow disappears, perhaps the arrow reproduces features also of the notochord. This is the semi-cartilaginous rod that disappears in some creatures, its place being taken by the bony neural arch.

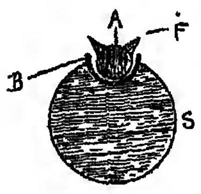


FIG. 69.
DIAGRAM OF SECTION OF CROSSBOW'S STOCK

A, arrow (notochord); B, barrel (neural arch); S, stock (body cavity); F, feather (spinous process).

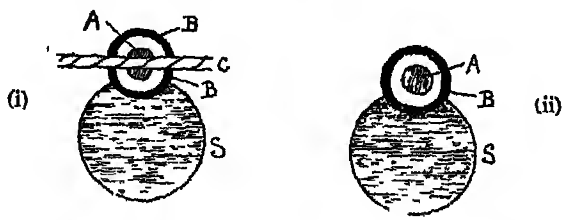


FIG. 70. DIAGRAMS OF SECTIONS OF STOCK, BARREL, AND ARROW OF SLURBOW

(i) Where barrel is slit
(ii) Where barrel is fully formed
A, arrow; B, barrel; S, stock; C, strings

In the ordinary crossbow machine, the neural arch has the

form of a semi-circle, *Figure 69,* and is formed only under the arrow, or spine or notochord; and does not enclose the arrow. But in the slurbow machine, a section through the part where the strings slide along the split barrel shows the neural arches above and below the arrow, but still not meeting at the sides where the strings slide through the barrel, *Figure 70* (*i*). A section through the part where the barrel is fully formed and complete, however, shows the neural canal completely formed, *Figure 70* (*ii*). The neural canal is completely formed at the muzzle of the Chinese repeating crossbow machine; and for the whole length of the barrel of the Ba-kwiri crossbow machine.

The neural arch of a crossbow is usually formed by some hard material, like brass or horn. When the barrel, or neural arch, is of brass, there is no close correspondence between the material of the mechanical neural arch and the material of the human neural arch. But when the barrel is of horn, there is a closer correspondence of materials.

The neural arch in crossbows whose barrels are formed merely by a groove in the wood of the stock is not made of material separate and different from that of the stock. The arch is then formed merely by the surface of the groove in the wood. The Fan crossbow's neural arch, for example, is formed merely by the slight scratch or groove in the top of the stock, and is hardly evident

Hence, sections of various types of crossbows through the stocks and barrels at right angles to the axes of the barrels show different stages in the development of the neural arch; and its development from the slight depression in the body cavity to the fully formed arch separately formed from the body cavity can easily be traced.

Elementary and rudimentary forms of the neural arch can also be seen in the bow and arrow machine. The neural arch is of horn in the Mongolian horn groove machine, of iron in the Egyptian iron groove machine, of wood in the Siamese wooden groove machine, and of cane in the Korean cane groove machine. The arch is formed only on the under side of the arrow, except in the Korean cane groove

machine, in which the cane groove nearly surrounds the arrow and forms almost a complete neural arch.

The siper, or mechanical groove used by an archer, it has been shown in the first part of this work, is derived from the flesh groove made in the left hand fingers as the fore-shaft of the arrow lies on them. Hence the mechanical neural arch is derived from this human device. It is directly derived from the human flesh groove device, but is developing to reproduce the neural arch of the backbone. The siper and the barrel of a gun therefore reproduce the flesh groove of the fingers in the offensive system, and reproduce the neural arch in the reproductive system.

The string or cord of the bow possibly corresponds to the spinal cord. The author is not clear about this however, but no doubt his readers will solve this problem. The following remarks about the bow strings should therefore be received with some caution and be regarded merely as suggestions which may help in the solution of the problem.

The cord of the crossbow traverses the length or much of the length of the neural canal; that is, it slides along the barrel of the crossbow. It does not lie wholly in the canal, or barrel, as the human spinal cord lies in the neural canal or nervous column of the backbone. But the differences in positions of the mechanical and human cords can perhaps be accounted for on the supposition that the mechanical cord is turned through a right angle compared with the axis of the mechanical backbone or barrel. That this is so is also suggested by the fact that the cord of the bow is turned through a right angle together with the bow arms and lies along or nearly along them. In various staff slings the cord does indeed lie along the shaft. In the Malabar crossbow machine the spinal cord also lies alongside and parallel to the neural column, if as is probably the case the harpoon line is an extension of the spinal cord. Indeed, before the harpoon is shot, the line connecting the harpoon to the crossbow lies neatly coiled in a small bamboo cylinder (*see Figure 63*), which is close to the neural canal of the crossbow, formed by the groove or barrel. The bamboo cylinder is perhaps

an extension of the neural canal, placed as near to it as possible; and it can be noticed that although the part of the canal formed by the barrel is semi-circular in section and is therefore not fully formed, the part formed by the bamboo cylinder is circular in section and fully formed. The Malabar crossbowman it seems has solved fairly satisfactorily the problem of providing a mechanical weapon with a fully formed neural canal enclosing a spinal cord, but only by the expedient of giving the partly formed neural canal or barrel an extension. This problem has been more satisfactorily solved by the maker of the toy pop gun, for the cord lies inside the fully formed barrel of the pop gun, which consists of a tube closed by a cork to which a cord or string is fastened, the cord or string lying coiled in the barrel which of course corresponds to the neural or spinal canal. When the plunger is operated, the compressed air drives out the cork, and the cord or string then lies partly outside the neural canal.

In the thrusting spear machine, the neural canal is formed by the hands as they grasp the shaft, and is wholly human. The backbone and body cavity are reproduced by the shaft, but are not separately mechanized, as they are in the crossbow and gun machines. Spinous processes are reproduced in mechanical forms if the spear has barbs; but if it has no barbs, the processes are still reproduced but only in human forms, by the twenty eight knuckles or barbs of the fists.

The section of the shaft of a thrusting spear at right angles to the axis of the shaft shows features which correspond to those shown by a section of an invertebrate creature; but the section of a crossbow or gun at right angles to the axis of the barrel shows features which correspond more to those shown by a section of a vertebrate creature. According to zoologists, invertebrate creatures are distinguished from vertebrate creatures or creatures with backbones mainly by having a single tube containing all the vital organs, while in vertebrate creatures if the body is cut transversely a section shows two main tubes, in the larger of which are the alimentary canal and haemal or blood vessels and some parts of

the nervous system; but the main mass of the nervous system is represented by the spinal cord.* In the thrusting spear machine, all mechanical parts are contained within the single tube of the spear shaft; but in the crossbow and gun machines the mechanical parts are contained in two tubes, one tube being the barrel and the other and larger tube being formed by the stock supporting the barrel.

* e.g., T. H. Huxley, LL.D., F.R.S., *The Anatomy of Vertebrated Animals;* and *The Classification of Animals.*

CHAPTER 49

THE GUN

IN the ordinary bow and arrow machine the backbone of the wielder is reproduced by the shaft of the arrow; and the spines of the wielder's backbone are reproduced externally and given mechanical extensions by means of the barbs and feathers of the arrow. In the bow and arrow machine provided with a groove fastened to the left hand, the backbone is also partially reproduced by the horn groove; and the beginnings of a process can be seen in which the backbone formed by the arrow is eventually replaced by a backbone formed by the metal barrel of a gun. The arrow developes into a ball or bullet which then reproduces more particularly other parts and devices of the reproductive machinery. In various types of the siper machine, or bow and arrow machine provided with a mechanical groove, can be seen stages by which the backbone becomes almost completely formed round the arrow. In the Korean groove variety, the backbone is fairly well reproduced by the cane siper; but the backbone is still also represented by the shaft of the arrow. The neural arch can be seen developing around the arrow, until in some crossbows, like the Ba-kwiri crossbow, the neural arches meet and form a neural canal or spinal column.

The gradual transference of the spinous processes from the surface of the arrow to the interior surface of the barrel can also be observed. In the siper machine, the mechanical parts of the spinous processes are entirely on the arrow, and no parts are on the barrel or groove which is smooth. But the interiors of some crossbows are rifled; and the rifled grooves are the feathering devices transferred to the interiors of the tubes or barrels.

In the early cannon machine, when the missile was a padded and barbed and feathered arrow, the spinous processes were

on the surface of the arrow, and no spinous processes, in the forms of rifled grooves, were reproduced by the barrels of the cannon. It was many years before it occurred to the makers of guns to try and transfer the rifling devices to the interiors of the barrels; and no mechanical riflings were provided when the arrow type of missile was replaced by a ball of iron or stone. But in the modern gun machine the riflings are partly mechanized and externalized by means of the rified grooves; and the spinous processes are formed by the lands, or parts of the gun barrels which are not removed when the rifled grooves are made. The spinous processes are not on the outer surface of the backbone, or barrel, but on the interior, and project towards the interior of the spinal column of the barrel. They are therefore reversed compared with the human spinous processes which project outwards (Rule 11).

The riflings, or spinous processes, are not fully transferred from the missile, in the gun machine; for they are still formed on the external surface of the bullet or on the driving band of the shell, and these are transferred copies of those on the interiors of the barrels, being transferred as the missile is being driven through the barrel.

The missile of the modern gun has therefore to a great extent ceased to reproduce the backbone, although certain features of it are still reproduced by it; and the backbone is now reproduced mainly by the barrel. The metal tube does not correspond closely in materials to the materials of the backbone, for steel does not reproduce the characteristics of bone very well. It does reproduce the hard and rigid characteristics of the bone; but does not reproduce its structure, although perhaps there is some correspondence between the molecular structure of steel and bone, which however must be very remote. The metal barrel does not reproduce the separate joints of the vertebrae; and is merely a continuous tube.

The spinous processes, represented by the lands, are of no great depth; and are much less prominently formed than in the bow and arrow machine by the barbs and feathers. But

the feathering on a crossbow is sometimes very slight. Thus, for example, arrows for the Chinese repeating crossbow are sometimes so slightly feathered that the feathering can be seen only by close inspection. The feathering on an arrow therefore sometimes is not deeper than the rifling on a gun barrel. The number of spinous processes on the interior surface of a gun is of course equal to the number of rifled grooves; and varies in different types of the gun machine.

The spinous processes in the gun machine are not fully mechanized; for no human device or contrivance can be fully mechanized. If it could be, then the mechanical device or contrivance would become independent of the body, and would become a living creature capable of acting independently of the body and with a will of its own; and if such a state of affairs were to be brought about, we might see a gun deciding to take offensive actions by its own volition; and this would be as strange as, say, a club suddenly moving from the place where it had been placed and getting up and hitting somebody on the head. No weapon or part of a weapon can have any life except in so far as it is provided by the wielder; and all actions and movements of a weapon are primarily and wholly derived from the wielder. Types of missiles are made nowadays which do seem to be independent of the wielders, to some extent, when in the air; but the movements and actions of the missiles when in flight are dependent on and derived from the mechanisms of the body of the wielder, who can indeed be unconscious that his mechanisms are still connected and related to those of the missile. That they are still connected to the missile is shown by the fact that, as was shown in the first part of this work, the trajectory is part of the offensive machine. It is also shown by the fact that wielders of these types of missiles are trying to obtain better control over them after they have been loosed into the air. It is also shown by the fact that the person who makes and sets in motion one of these missiles is regarded as responsible for its actions.

Some evidence was given in the last chapter to show that the shaft of an arrow reproduces some features of the body

cavity. A gun barrel, it will now be shown, reproduces many features of the body cavity.

The alimentary canal in vertebrate creatures is in the larger of the two tubes shown by a section of the body at right angles to the backbone. The mechanical extension of the alimentary canal in the gun machine is reproduced in the larger of the two tubes shown by a section of the rifle at right angles to the axis of the barrel, that is in the section of the wood of the stock; but is reproduced at best only in a very rudimentary way. It is reproduced also only if the theory is correct, as it probably is, that the structure of wood reproduces features of the structure of the body. The alimentary canal of the gun machine is however very clearly reproduced as a mechanical extension of the wielder's alimentary or food canal by the gun barrel itself.

It was forced upon our notice in the first part of this work that the gun barrel reproduces parts of the genital organs, and in particular the penis. But it also, it will now be seen, reproduces the alimentary canal. The spinal column and penis and alimentary canal are separate tubes in man; but are not separately reproduced in the gun machine; and the barrel reproduces simultaneously features of the spinal column, penis, and alimentary canal.

The muzzle is the mouth of the gun. The word muzzle is probably derived from or related to the Latin word *mordere*, to bite; and for example, the muzzle of a dog or horse is a device placed on the animal's mouth to prevent it biting anyone; and to muzzle anything means to stop its mouth or to restrain it from biting. But there can be no doubt that the muzzle of a gun forms its mouth, for phrases like "the cannon's mouth" are in common use. Muzzle loading guns are fed through the mouth; and some of the materials fed to a muzzle-loading gun are ejected through the mouth after undergoing a process of combustion which has some resemblances to but is much more rapid than the process of combustion which occurs when food is consumed or burnt in the body. According to authorities on the gun, it is wrong to speak of an explosion occurring in a gun, but correct to

speak of the combustion of the charge. Thus Burrard writes: — "The powder charge is commonly said to 'explode', but this is an incorrect description, for powder definitely burns; and this combustion, although rapid, is by no means instantaneous . . ."[1] It is widely understood nowadays also, that food taken into the body undergoes a process of combustion or burning. There are therefore some similarities, or correspondences, between the processes that occur when food is consumed in the body and when powder is consumed in the gun barrel.

The waste materials are ejected from the mouth of the gun. Waste products of combustion are not ejected through the human mouth, but through a separate aperture. The procedure in the gun machine is however the same as that in those creatures in which waste products are ejected through the same aperture as the one through which food is taken in.

The breech loading gun is an extraordinary organism; for it is fed through its anus, and it ejects waste materials through its mouth, thus, as it were, reversing the natural procedure. According to the dictionary the word breech can mean "either the lower part of the body behind or the hinder part of anything and especially of a gun." The opening at the breech therefore corresponds to the anus of a creature. Nowadays most guns are breech loaders, and are fed through the anus and eject waste materials which include burnt gases, bits of unburnt powder, and the missile, through the mouth. Although the procedure of taking in food through the anus and ejecting materials through the mouth is the opposite to that followed by the organisms of the wielder, the reversal is in accordance with Rule 11.

Many creatures have a nearly straight tube running through the body, into which food enters at one end and from which waste materials are ejected at the other end. The common earthworm's alimentary or food canal, for example, is such a type of tube. In man and many other creatures the alimentary canal is very long, and is not straight but is convoluted and twisted back upon itself many times. Some of the

[1] *The Modern Shotgun.*

features and characteristics of the alimentary canals of creatures with straight tubes are therefore reproduced by the barrels of guns; and gun barrels do not reproduce the turns or convolutions of the human alimentary canal. It will be shown later that the convoluted alimentary canal is reproduced by the alimentary canal of the internal combustion engine.

The shaft of an arrow or of a spear reproduces the stomach, and that of a whip the crop. The missile of the gun machine does not reproduce the stomach or crop, unless the missile is an arrow, as was the case in the very early cannon machine; and instead the stomach or crop is reproduced by the barrel. In creatures with straight alimentary canals, like the earthworm, the stomach or crop is not usually well formed. Somewhat similarly in the gun machine the mechanical extension of the stomach is not well developed, unless the gun has a magazine. If it has a magazine the mechanical stomach is well developed, and reproduces several features of the stomach of the body. The word magazine means "storehouse"; and since the cartridges are stored in it before going into the alimentary canal, the magazine evidently corresponds to the stomach or crop. It has been already explained that the magazine reproduces the scrotum, and that it is the storehouse or chamber for the balls or bullets which correspond to the testes; and that it is also the storehouse for the spermatozoa, the balls or bullets also reproducing the spermatozoa or seeds. The scrotum and the stomach are therefore not separately reproduced by the mechanical parts of the gun machine; and in the weapon the scrotum is in the stomach, and it can also be said the stomach is in the scrotum.

Other contrivances related to the magazine are the archer's quiver, slinger's bag or pouch, billiard table pocket, and the pocket of the golfer's bag which contains or holds the balls. The billiard table's pocket is at the height of the average player's scrotum, and is at the top of the legs of the table which are extensions of the players' legs. The golfer's bag, of the type much used until recently, is carried by being

slung over the shoulder with the small pocket or pouch on a level with the human scrotum. It has been explained that unless in transferred positions, mechanical parts are always found near their human counterparts.

The mechanisms of the lock of the rifle which place the cartridges in the breech must correspond to and reproduce the human contrivances which push the food from the stomach into the smaller intestine, and must also at the same time correspond to and reproduce the mechanisms which expel or push the spermatozoa from the scrotum into the penis.

When a rifle is fired, an impulse is sent along the barrel and transmitted to the opposite end of the trajectory, to the opponent or target which then receives the impulse. Probably this impulse is of the same type as that sent along the spinal column of a creature. It seems therefore that when a bullet is fired, some of the principles by which impulses are transmitted along the spinal cord are demonstrated in a very simple and elementary way. The velocity of the impulse in the case of the rifle machine is sometimes about 2,600 feet a second. It is therefore not instantaneous. This shows that the impulse sent along the spinal cord of a creature is not instantaneous. But the speed of the impulse varies considerably in the different types of the offensive or reproductive machine. The velocity of the impulse given by the arrow of the bow and arrow machine is less than that given by the bullet of the gun machine. The impulse from the stone throwing machine is still slower in operation. It is likely therefore that the velocity of the impulses along the spinal cord is not constant, but varies according to the type of creature, and varies somewhat also in different creatures of the same type.

PART III

THE LOCOMOTIVE MACHINERY

Chapter 50

SHOES

MAN uses two main methods of progression, walking and running. Walking and running can be accomplished without artificial aids. When a person walks or runs bare-footed, he has no artificial aids to progression. But usually artificial aids are used. The commonest are sandals, shoes, and boots. These protect the feet from hard and sharp surfaces, allow a better grip of surfaces to be obtained, and help the walker or runner in other ways. Various other aids are used to help in progression. Some of these will be studied, and from the study much will be learnt about the principles of locomotion; for the artificial aids are used in conjunction and work in harmony with the locomotive machinery of the body, and a study of them made with reference to the locomotive machinery of the body will help us to understand how the locomotive machinery of the body is constructed and works.

A shoe or sandal is one of the oldest and most familiar mechanical aids to locomotion. The fitting of shoes or sandals affects the locomotive machinery of the body in a multitude of ways, a few of which will be briefly noticed.

When shoes are worn, the body moves at a slightly greater height above the ground than when the walker moves bare-footed; and the increase in height is equal to the thickness of the soles of the shoes. The length of the stride, since the length of the leg and shoe is greater than the length of the leg alone, is usually a little longer than when no shoes are worn. The weight of the shoes makes the movements of the legs slower and more ponderous.

The soles of the feet do not make contact with the ground, and contact is made by the soles of the shoes instead, the soles of the shoes replacing the soles of the feet in this task. The wear and tear of the ground is experienced

mainly by the soles of the shoes. The human soles are provided with machinery which, in co-operation with other machines of the body, can repair the wear and tear experienced in walking on natural surfaces like grass, moss, and sand. But the wear and tear from artificial surfaces like roads and pavements is too great for nature's machinery to repair. The function of nature in repairing the soles can be copied distantly and crudely by repairing or replacing the shoes when worn.

Each shoe is made to perform the same actions as the foot to which it is fitted. When the left foot goes forward the left shoe goes forward. When the rear foot makes a movement of thrusting on the ground, the thrust is transmitted to the sole of the rear shoe which directly thrusts on the ground and gives the impulse which propels the walker forward. Conversely, the movements of the shoes are transmitted to those of the feet. If, for example, the left shoe catches in a projection, say a stone or stick on the ground, it transmits the shock to the left foot and causes the walker to stumble. If the walker turns to the left or right, the shoes are turned to the left or right. If the walker stops, the shoes become stationary. When a shoe is fitted, neither the foot nor the shoe can have independent or different movements, and both foot and shoe must move and act together, performing exactly the same movements and actions. It is evident that a shoe becomes part of the locomotive machinery when fitted to the foot; and must be studied as an integral part of the machinery.

When a shoe is fitted to a foot, many of the locomotive actions of the foot are no longer directly made by the foot, and the foot acts indirectly through the agency of the various parts of the shoe. When a walker is bare-footed, his rear foot thrusts directly on the ground to give the impulse to propel him forward. When he wears a shoe, his rear foot does not thrust directly on the ground, but thrusts on the surface of the inside of the sole of the shoe, and the outer surface of the sole directly thrusts on the ground and gives the impulse to propel the walker forward. If the shoe were

not attached to the foot, the sole of the shoe would be left behind after the impulse, but the straps or other parts of the shoe which hold it to the foot carry the shoe with the foot. The skin of the human sole is attached to the foot by various tissues and by the skin which surrounds the foot, and the human sole similarly is carried forward with the foot and is not left behind when a step forward has been made. The human sole has good frictional properties and a walker on natural surfaces when bare-footed does not usually slip, and finds little difficulty in progressing. But when walking with shoes on an artificial surface like a road or a pavement it is sometimes necessary to improve the frictional properties of the soles of the shoes, which may then be provided with projecting nails or studs to prevent slipping.

A shoe corresponds in shape and size to the shape and size of the foot for which it has been made. A shoe should be made for the wearer. When shoes are "ready made", the person who wishes to buy a pair usually tries on several pairs and chooses the pair that fits him best, i.e., he chooses the shoes which correspond best in shapes and sizes to the shapes and sizes of his feet. The type of shoe chosen depends on the purpose for which the wearer needs the shoes. If he wishes to walk, he chooses shoes suitable for walking; if to run, for running; if to dance, for dancing; and so on. Different types of shoes must be used for different purposes, for the locomotive machinery acts differently when walking, running, dancing, etc., and the shoes must work in harmony with the ways in which the locomotive machinery will work.

[Shoes worn for dancing form parts of the dancing machinery, which is the machinery of the body formed for dancing, e.g., for performing the waltz, polka, lancers, fox-trot, and other dances. This machine is perhaps a variety of the offensive and reproductive machine. This is suggested by the fact that the attitude of a dancer is very similar to that of the wielder of a weapon like a bow and arrow, cross-bow, or hand gun. When dancing, one hand and arm is stretched forward and the other is placed round the waist or on the shoulder of the partner; and if the partner were

removed, the weapon could be held with little alteration of position. This shows that essentially a dance is simultaneously an offensive and a reproductive activity. In the dance, each partner corresponds to an opponent in an offensive action; and the movements of each in reply or response to those of the other are even better shown than when two boxers or wielders of the fists are opposed. A study of the dancing machine has never been made; but it is fairly certain such a study would throw much light on the offensive and reproductive machinery of the body, and would at the same time reveal the significances of the various dances.]

CHAPTER 51

LOCOMOTIVE MOVEMENTS

WHEN walking, the heel is the first part of the foot that touches the ground. As the walker moves forward the weight of the body begins to be placed over the front leg, and as the body comes more above the leg the sole of the foot is placed on the ground. When the body passes over the foot, the balls of the toes take the weight. As the rear leg is brought to the front, a thrust is given by the toes of the foot which now has become the rear foot. The ankle during the movements of the foot and leg acts as a kind of pivot round which the foot is moved.

The actions of the ankle and foot and leg are much more complicated than the above statements suggest; but approximately and sufficiently for our purpose at the moment they are as described. It is impossible in the present state of knowledge of the locomotive machinery of the body to explain or describe fully all the actions of the various parts of the foot, ankle, knee, and leg, during their movements when walking; and only a few general and elementary statements can be made about them.

When running, the heel does not touch the ground. An inexpert or untrained runner may make his heel the first part of the foot to touch the ground, but the expert runner " runs on his toes ". The sole may just touch the ground in running as the foot is placed forward; but the sole, or flat of the foot, should not take the weight of the body. The balls of the toes first make contact with the ground as the foot is placed forward, and when the body comes over the leg, the weight is taken by the balls of the toes and the toes; and as the leg goes behind a thrust is given by the toes to propel the runner forward. When running the body is carried slightly higher than when walking.

The actions of the ankle when running are similar to its

actions when walking. They are too complicated to be fully understood, but in a general way it may be said the ankle acts as a pivot round which the foot turns when running.

The reader if he holds his right ankle by the thumb and forefinger of his left hand and then moves his foot up and down will notice that the foot moves round the ankle as if round a pivot.

Figure 71 shows diagrammatically the action of the leg and foot when walking, the foot however being regarded as incapable of moving round the pivot of the ankle. In *Figure 71* (*i*), the foot is ahead of the body and the heel is on the ground. In *Figure 71* (*ii*), the body is above the foot, and the sole is on the ground. In *Figure 71* (*iii*), the body is ahead of the foot, and the toes are on the ground giving a thrust to propel the body.

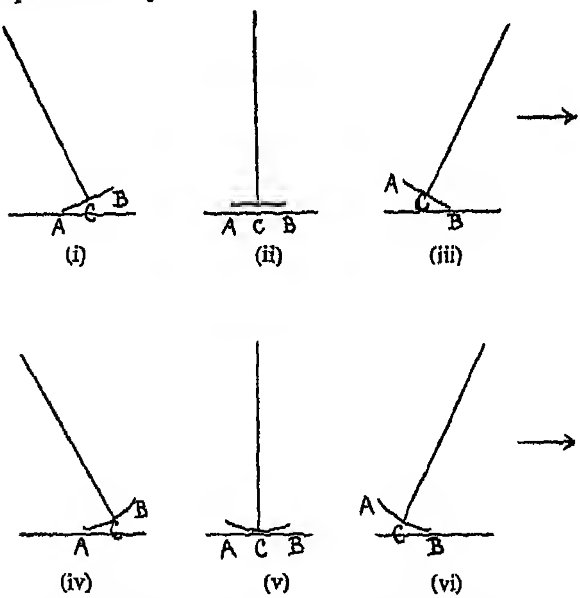


FIG. 71. DIAGRAMS OF ACTIONS OF LEG AND FOOT AND OF ACTIONS OF SPOKE AND FELLOE

Figure 71 also shows the action of a spoke of a wheel. In *Figure 71* (*iv*), the felloe, or part of the rim which forms the

foot of the spoke, is ahead of the hub, and the part of the rim A is in contact with the ground. As the vehicle moves forward the spoke comes into an upright position as in *Figure 71* (*v*), and the part of the rim C directly under the spoke then takes the weight of the vehicle. As the vehicle continues its progress the spoke comes into the position shown in *Figure 71* (*vi*); and the part of the rim B makes contact with the ground, and gives the thrust to propel the vehicle. Before the vehicle can collapse on the ground, another spoke comes into the forward position as in *Figure 71* (*iv*), and the action of placing one spoke in front of another as one leg is placed in front of another is automatically and crudely performed by the device of the wheel. The spoke shown in *Figure 71* (*vi*), ceases to be an active spoke when the rim A C B leaves the ground; and the leg of the vehicle is then formed by the succeeding spoke.

If the parts and actions of the leg and spoke in the two diagrams are compared, it will be seen that the spoke corresponds to the leg, and the part of the rim A C B corresponds to the foot, and the point C to the ankle; and that the actions of a leg are crudely but approximately reproduced by the actions of a spoke.*

The part of the rim A C B is not pivoted at C, but is rigidly joined to the spoke. Since it is curved in the arc of a circle, the hub moves in a straight line without an up and down movement. An up and down movement of the human body is prevented by a very complex arrangement of muscles and joints working together. [1]

Although a wheel may have many spokes, only a few of them are locomotive spokes at any moment. The others are

[1] G. M. Humphry, M.D., F.R.S., *The Human Foot and the Human Hand.*

* " . . . the human body is fitted out on a wheel . . . it is a wheel with only two spokes, with a hub at the hip-joint and felloes or rim at the feet. But because these spokes are movable, first one swinging forwards and then the other, they are able to do the work of the twelve spokes which are fixed together in a circle so that they come in contact with the ground one after the other. A wheel is really a great number of legs and feet set together so as to move round in a circle . . . " Sir Arthur Keith, M.D., LL.D., D.Sc., F.R.S., *The Engines of the Human Body.*

merely struts or stays, whose purpose is to keep the shape of the wheel. A wheel with say six or eight spokes may indeed have only one locomotive spoke at any moment, this spoke being the one joined to the felloe which at that moment is on the ground; because the weight of the vehicle is borne mainly by this spoke, and it is the only one performing a leg action. The other five or seven spokes at this time act merely as struts or stays.

A wheel having wire spokes is a suspension wheel; and the weight of the vehicle is not placed on the lowest spokes but is suspended from the highest ones. In a bicycle wheel with say thirty two spokes, probably only three or four of the uppermost spokes are locomotive spokes at any moment, and the rest act merely as stays to keep the shape of the wheel. When comparing the locomotive devices of the body and of a vehicle, it is therefore necessary to consider only the locomotive spokes of a wheel. The rest need not be considered, because they are not locomotive spokes but merely struts or stays. The locomotive spokes of a wheel with solid spokes are directed downwards and move through an angle which cannot be more than two right angles. But the locomotive spokes of a suspension wheel point upwards, and are therefore reversed in positions compared with those of a wheel with solid spokes (Rule 11). The human spokes, formed by the legs, point downwards; and cannot move when a person runs through more than two right angles.

The actions of a spoke of a wheel reproduce in a crude manner some of the actions of the leg in walking, and the actions of the part of the rim near the spoke reproduce in a crude manner some of the actions of the foot; and it is evident that a wheel is a device or contrivance by means of which the actions of placing the legs alternately in front of each other can be crudely reproduced mechanically.

The original form of the wheel and the stages by which the wheel has been evolved are not known. One early form of the wheel, it is thought, was probably a log; and the log may later have had its middle portion reduced in diameter so that a kind of axle was formed. Another early form was two

disks of stone or wood fastened to a rigid axle. But although it would be interesting and might be important to know how the wheel originated and evolved, the end to which the pioneers of the wheel were working although probably unknown to them is clear to us now. Unconsciously the pioneers were trying to reproduce mechanically the structure and actions of the locomotive machinery of the leg and foot. Only when the spoked wheel had been developed could the goal of their labours have been seen; for a log, or a pair of disks joined by a rigid axle, reproduces the structure and copies the actions of a leg and foot so crudely that the correspondence of structure and actions cannot easily be seen.

The process of developing the wheel has taken many centuries, and the process was begun almost in the dawn of civilization. Today the locomotive actions of legs are still only crudely reproduced by the wheels of vehicles, and the actions of nature's locomotive machinery cannot yet be copied with much accuracy. It can however safely be stated that each improvement in wheel devices for vehicles which will be made in future will help towards reproducing more closely the locomotive actions of legs, and will make correspondences between man's devices and nature's more evident.

CHAPTER 52

THE WALKING STICK AND STILT

ONE of the simplest devices used by a walker to obtain help in progression is a walking stick. A study of the ways in which a walking stick becomes part of the locomotive machinery of the body of the walker is important, because when it is fitted to the body it becomes an elementary type of spoke, related to the spoke of the wheel of a vehicle. It is also closely related to the club, and if it has a knobbed end and is reversed can be used as a club. It is also closely related to the thrusting spear, and can be used as a type of thrusting spear. A few ways of using it as a help in progression will be briefly noticed.

In the first way, the handle of the stick is held always slightly ahead of its point, or base, with the shaft inclined at an angle of about thirty degrees to the vertical. The right hand holding the handle moves opposite the left leg; and is forward when the left leg is forward, and back when the left leg is behind. The base of the stick is placed on the ground at the side of the right foot when the right foot is behind and about to make a thrust on the ground to propel the body. It remains in contact with the ground after the right foot has moved forward and until the left foot makes its thrust on the ground.

The base of the stick meets the ground just in time for the walker to give a thrust with his stick to help the thrust given by the right foot. Since it remains in contact with the ground until the left foot makes its thrust, the walker is able to use the stick to help the left foot as well as the right foot to make its thrust. In this way of using the stick, the walker can use it to help the thrusts of each foot in turn.

As the left foot finishes its thrust on the ground and begins to move forward, the walker lifts the stick off the ground and brings it forward, but still keeps it inclined at the same angle

to the vertical. The right hand moves forward until it is opposite the place where the left foot is placed on the ground. The stick is then placed once again on the ground, but because it is inclined at about thirty degrees backwards, its base instead of touching the ground opposite the left foot touches the ground at the side of the right foot. The movements are then repeated, as described above.

When the right or left foot is behind and making its thrust on the ground, the leg is not much bent at the knee and is almost straight and inclined at about thirty degrees to the vertical. When the base of the stick is on the ground just at the side of the right foot, the stick is alongside the right leg, and the stick and leg thrust on the ground together in parallel directions and from almost the same place.

When the left foot is making its thrust the stick, not having been moved forward when the right foot went forward, is nearly opposite the left leg and parallel to it; and the stick and left leg thrust on the ground together and in nearly parallel directions.

When walking without a stick, the hands swing backwards and forwards, the right hand being opposite the left foot, and the left hand opposite the right foot. This natural rhythmical movement of the hands is performed when the walking stick is used in the manner described above, for the right hand holding the handle moves in time with and opposite the left foot, and the left hand moves in time with and opposite the right leg. The movements are however not quite so free and the hands do not move to quite as great an extent as when no stick is used. The walking stick is used in this manner usually by an able-bodied walker who however needs or likes some help in progression.

The amount of help to progression given by use of the stick depends on the amount of thrust given by the hand to the stick when the stick is in contact with the ground. A considerable degree of help may be given, or very little may be given. A small proportion of the weight of the body is borne by the stick and taken off the left leg, because the stick is on the ground during the time the left foot is on the

ground, and the walker leans slightly on the stick. The stick is off the ground when the right foot is on the ground, except for the moment the right foot is making its thrust, and therefore the right foot is not relieved of any of the weight of the body. Indeed, the right foot has to bear the weight of the stick in addition to the weight of the body

If a walker has the help of a staff instead of a walking stick, he uses it in much the same way as described above; but since he grasps the staff at about the height of his breast or shoulder, he depends from the staff and does not lean on it.

In the second way of using a walking stick, the stick meets the ground near the right foot as the foot is about to leave the ground. Instead of meeting the ground again when the right foot next goes behind, the stick is brought back by the hand so that it is inclined at an angle of about thirty degrees to the horizontal, the point, or base, of the stick being higher than the hand. It meets the ground again near the right foot as the right foot then goes behind, the right foot and stick being together on the ground only at alternate steps of the right foot. A walking stick is used in this way by a smart and quick walker who does not require much help in progression. The natural rhythm of the hands is not much affected, and indeed may be helped.

No appreciable portion of the weight of the body is borne by the stick, but a slight thrust is given by it as the right foot makes its thrust; and a slight thrust is also given by the stick as the left foot makes its thrust, the base of the stick remaining in contact with the ground from the moment the right foot makes its thrust to the moment the left foot makes its thrust. In this way of using the stick both feet are helped in turn when making their thrusts on the ground to propel the walker forward. Because the stick is carried and not placed on the ground for the next steps of the right and left foot, the right and left feet are helped in making their thrusts only on alternate steps.

In the third way of using a walking stick, the right hand holding the handle moves opposite the left foot. The stick is kept vertical, and its point is placed opposite the left foot,

and remains on the ground while the left foot is on the ground. Sometimes, instead of being kept vertical, it is inclined slightly forward and makes contact with the ground slightly ahead of the left foot. The walking stick is not used in this way by a brisk walker, but commonly by old or slightly infirm people. The walking stick acts as a support for the left leg. The walker leans on it, and places some of his weight on the stick instead of placing all of it on the left leg. The left leg is helped in making its thrust. Clearly, the stick, since it works with the left leg, corresponds to the left leg.

In the fourth way of using a walking stick, a way used mostly by infirm people or cripples, the hand is held against the right groin, and the stick remains always alongside the right leg. It meets the ground when the right foot meets the ground, remains on the ground while the right foot remains on the ground, and is lifted off the ground when the right foot is lifted off the ground. The hands do not swing in time with the opposite legs, since the right hand is kept against the right groin, but the left hand may be swung in time with the right leg.

The walker leans on the stick when the right foot is on the ground and the stick bears part of the weight of the body and partly relieves the right leg of the work of bearing the weight of the body. The thrust which would be given wholly by the right foot if no stick were used is given partly by the stick. Nearly the whole weight of the body and most of the thrust can, if necessary, be borne by and given by the stick instead of by the right foot. Since the stick is lifted off the ground when the right foot is lifted, the left leg is not helped in its work of bearing the weight of the body or making a thrust to propel the body forward. Indeed, the weight of the stick must be borne by the left leg in addition to the weight of the body when the left leg is on the ground.

The above way of using a walking stick is useful when the right leg is not so strong as the left or is crippled. If the left leg is not so strong as the right or is crippled, it can similarly be helped if the stick is held in the left hand.

The base of the stick, in the first two ways of using the stick is placed in contact with the ground at the side of the right foot. The hand thrusts on the stick to help the right foot which then moves forward. The hand again thrusts on the stick, this time to help the left foot. The left foot however is a step in advance of the place where the right foot and stick were placed side by side; and therefore the stick must be of such a length that when the right arm and stick are in a straight line the base of the stick can just reach to one pace behind the left foot when it is behind the body.

A stick which is equal in length to about the distance between the heel and the groin allows the arm to straighten to its full extent as it gives its thrust on the ground to help the left leg. In the third way of using the stick since the hand holding the handle is at the groin the length of the stick will also be about the length of the distance between the groin and heel. The length of the stick, of course, varies according to the height and length of leg of the user, a tall man requiring a longer stick than a short man.

A walking stick forms a kind of additional leg. It therefore differs fundamentally from an artificial leg provided to replace a lost limb, because it works in harmony with its human counterpart. An artificial limb has no human counterpart with which to work, and is meant to replace a human limb. A weapon or implement like a walking stick does not replace a limb, but serves as an artificial extension for a human counterpart, and allows some of its powers to be extended. But much can be learnt about weapons and similar types of contrivances from a study of artificial limbs.

An artificial leg of a modern type resembles a human leg more closely than an artificial leg of an older type resembled it. An artificial leg of an old type was often a piece of wood in shape something like part of a broom handle, strapped or fastened to the body or stump of the leg. A modern artificial leg may consist of several parts each of which resembles superficially some particular part of the human leg.

The part of the leg to which a particular part of an artificial

leg corresponds can often at once be known because of similarities of shapes, sizes, positions, and ways of working between the artificial and human parts.

Correspondence of a particular part of an old type of artificial leg to any particular part of the leg was often not evident, but could sometimes be deduced from certain similarities of sizes and positions and ways of working. For example, the base of a modern artificial leg is sometimes formed by a part which resembles in shape and size the sole of the human foot. It is at the extremity of the limb, and forms the base on which the body rests when not resting on the other foot. This part clearly corresponds to the sole of the foot. The base of an old type of artificial leg however was often merely the small circular end of the cylindrical piece of wood, and bore no evident resemblance to the human sole. But although correspondence could not have been seen because of little resemblance between the base and the human sole, it could have been deduced because of similarities of position and use. The base of the stump was situated at the end of the artificial leg as the sole is situated at the end of the human leg. It formed the base on which the body rested when not resting on the sole of the sound leg. It gave a thrust alternately with the sole of the sound leg. Clearly, the base of the stump acted as an artificial sole, and corresponded to a human sole.

Parts of a walking stick do not evidently resemble particular parts of the body; yet each part can be seen to correspond to some part of the body, usually through certain similarities of size and ways of working.

Three main parts of a walking stick can be distinguished, the handle, the shaft, and the base. The handles of walking sticks are almost endless in variety. A common type of handle is semicircular in shape, with the convex side uppermost. The handle sometimes consists of a knob, sometimes it is barely distinguishable from the shaft. The shaft is usually straight, of circular section, and about half an inch or a little more in diameter, and usually tapers slightly from the handle to the base. The base may be formed merely by

the end of the stick; but is formed by the bottom of a ferrule, if one is fitted.

The handle corresponds to the hand. Correspondence can be deduced because of similarities of shapes, sizes, and ways of working. The flesh of the insides of the fingers and of the palm where it is in contact with the handle takes the shape of the handle because of the pressure exerted between the hand and handle, and a fairly close fit of the hand and handle is obtained.

The shaft corresponds to the leg between the groin and the foot, since the stick is parallel to the leg when it is making its thrust, and the length of the stick corresponds approximately to the length of the leg and partly relieves the leg of its work of bearing the weight of the body and making the thrust to propel the walker. When used in the third way, the stick corresponds to the right leg, for it lies alongside the leg at all times and partly relieves the right leg of its work. When used in the first and second ways, it is not so easy to decide to which leg the stick corresponds for it helps each in turn. When the right leg is making its thrust it corresponds evidently to the right leg; when helping the left leg it corresponds to the left leg. It appears therefore that the stick is an instrument which corresponds alternately to the right and left legs, and acts alternately as a supplementary right leg and a supplementary left leg.

It is not strictly correct to say that a part of a walking stick corresponds to a part of the human leg. More accurately, it should be said that the part of the stick or artificial leg corresponds to a locomotive device formed by the human leg. The complex tissues, arteries, veins, and other parts and devices of a leg are not reproduced at all in the structure of any part of a walking stick or artificial leg, and neither the part of the walking stick nor the part of the artificial leg come into organic relationships with the leg, but merely with the device formed by the locomotive machinery. The part of the walking stick or artificial leg merely reproduces in a crude and rudimentary manner some of the locomotive devices of the leg. Although it does not come

into organic connection with the tissues and arteries and veins, it does come into organic connection with the locomotive devices of the leg, and works in harmony with them. It will be convenient for brevity to say that a part of a walking stick or artificial leg corresponds to some part of the leg, if it is understood that the term "leg" merely implies the locomotive device formed by the leg. Similarly, if an artificial device is said to correspond to the hand, arm, or other part of the body, it should be understood that it corresponds merely to the locomotive devices formed by the hand, arm or other part.

A walking stick is placed alongside the human leg; a stilt however forms an extension extending beyond and projecting from the leg. We may notice two types of stilts. One type, often used by children, is made from poles about five feet long, with steps about six inches from the ground for the feet to rest upon. By means of this type of stilt each leg is given an extension of about six inches. A walking movement is crudely reproduced by the stilts as they are moved by the user.

A second and more useful type of stilt is that used in the Landes of Gascony. The stilts have stirrups for the feet about five feet from the ground, but possess no parts above the knees. The parts of the stilts above the steps are fastened to the legs. A long staff is used in conjunction with the stilts to prevent the stilt walker over balancing and falling when at rest, the staff and the two stilts then being used as a kind of tripod.

When on stilts the foot is raised above the ground to the height of the stirrup, or step, of the stilt, in the case of a stilt used in the Landes to about five feet above the ground. The sole of the foot does not tread on the ground, and the work of treading on the ground is performed by the base of the stirrup of the stilt (Cp. Rule 5). The base of the stilt replaces the sole of the foot in this work, but indirectly the human sole treads on the ground through the agency of the base of the stilt (Cp. Rule 4). The base of the stilt is not shaped like a foot, and no attempt is made by the maker of a stilt

to copy the foot, as, for example, is made by a shoe-maker who makes the sole of the shoe correspond in outline to the human sole. An advantage obtained by raising the foot above the ground is that the foot remains dry and clean when the stilt walker passes over wet and dirty ground. An advantage obtained by using the artificial sole, formed by the base of the stilt, instead of the human sole is that the wear and tear of the human sole is prevented, and the wear and tear occasioned by progression is taken by the base of the stilt.

The fitting of the stilt allows longer strides to be taken, and a stilt walker appears to take very long strides. The stilts are made to perform walking movements, each stilt being placed alternately in front of the other. The actions of a stilt walker however are very clumsy and stiff, the actions of the locomotive machinery of the body when fitted with stilts being proverbially "stilted".

Each stilt is moved by the leg to which it is fastened and cannot have movements independent of or different from those of the leg. A stilt, for example, cannot be made to move forward when the leg to which it is fastened is moved backwards. The movements of the foot and base of the stilt are similar. Each part of the stilt is indeed made to perform movements and actions similar to those of its corresponding human part. The leg of the stilt makes movements and actions similar to those made by the leg for which it forms an extension. When the leg is raised or lowered, the leg of the stilt ascends or descends. When the leg is moved forward, backward, or sideways, the leg of the stilt similarly moves forward, backward, or sideways to correspond. The base of the stilt, or rudimentary artificial sole of the locomotive machinery must perform movements and actions similar to those of the human sole above it. When the human sole is raised, the base of the stilt rises; when the human sole is lowered, the base of the stilt descends; and so on. Similarly, the part of the stilt strapped to the leg partakes of all the movements of the leg to which it is strapped.

The body is supported partly by the legs and partly by the stilts. When a leg goes behind, it gives a thrust to move

the walker forward. This thrust is transmitted to the ground directly by the stilt, and the sole does not directly press on the ground, but presses only indirectly on the ground through the agency of the stilt. The leg of the stilt and its base therefore partly take over the work of the leg and sole, and perform a work performed in somewhat the same manner by the leg and sole when walking without stilts.

As has been stated, the human locomotive device to which any artificial device is intimately related and to which it may be said to "correspond", can be known from the position of the artificial device. The artificial device usually is in contact with its corresponding human device, but may be "transferred". A left shoe is specially related to the left foot, for it is made for the left foot, and is used by it, and is fitted to it, and partakes of the actions and movements of the left foot. It "corresponds" to the left foot, and of course, is always used by the left foot. It would not be found on the right foot, for it does not correspond to the right foot and could not work well with it. The way an artificial device can be transferred is stated in Rule 8 which says that a device can be transferred from one end of a part to the opposite end of the part. Examples of the ways parts of weapons are transferred have been given. Two simple examples will now be given to show that the transferring Rule applies also to locomotive contrivances.

The base of a stilt, it has been shown, acts as a kind of rudimentary mechanical sole. The base is a separate device of the stilt although it may not be separately made and may be, and indeed usually is, merely the end of the stilt. If a ferrule or stud were placed on the end of the stilt then the device would be a separately made device. The artificial sole of the locomotive apparatus, whether separately made or not, is not found near the human sole to which it is specially related and to which it corresponds, but is found at the end of the leg of the stilt opposite the human sole, having been transferred from the part of the stilt where the human sole is placed to the opposite end near the ground. Again, the part of the stilt below the leg corresponds to the human

leg above it, for it bears some rudimentary resemblances to it and performs similar actions and movements. It is however not found alongside the human leg, but is found below it, as an extension for it, having been transferred to the bottom of the human leg; and the foot of the stilt, formed by the lowest part, has been transferred to a place near the ground.

The sole or base of the locomotive apparatus, it should be noticed, has not been fully transferred from a position at the base of the human leg to a position at the end of the stilt near the ground, for the step, or stirrup, in which the foot is placed is a kind of sole, and is in the usual position of an untransferred device, namely, near to and in contact with the human part to which it corresponds, the part to which it corresponds being, of course, the human sole. The base of the stilt is therefore a device which has been only partly transferred from a position near the human sole to a position at the end of the stilt near the ground. The complete sole of the locomotive machinery is formed partly by the human sole, partly by the sole of the shoe worn by the stilt walker, partly by the stirrup, and partly by the base of the stilt.

The sole of the stilt walker is therefore in four parts. One part is human and the other three parts are artificial. The human part is the sole of the foot of the stilt walker. This human part does not tread on the ground, and does not experience the wear and tear occasioned by progression, nor does it become wet and dirty in passing over wet and muddy ground. The three artificial parts are the sole of the stilt walker's shoe, the stirrup or step on which the shoe rests, and the base of the stilt. Three of the devices are close together, namely the human sole, the sole of the shoe, and the stirrup; but the part of the sole formed by the base of the stilt is transferred to the end of the stilt opposite the foot.

The four parts work together and have similar movements, but the parts do not move to the same extent. Because the sole of the shoe is below the sole of the foot, when the leg is moved it is moved through a slightly greater distance than

the sole of the foot. The stirrup is below the sole of the shoe, and therefore it is moved a slightly greater distance than the sole of the shoe. The base, however, because it is at the bottom of the stilt is moved a considerably greater distance than the stirrup at each step.

As a rule a locomotive device resembles the human device to which it corresponds. Sometimes the resemblance is unmistakable; sometimes there is only a rudimentary resemblance. Thus, a shoe resembles a foot in shape, and its sole resembles the human sole in shape. But the base of the stilt, which is a rudimentary type of shoe or sole, has only the most distant resemblance to the human sole.

When a stilt is used, the base of the stilt instead of the sole of the foot makes contact with the ground. As a general rule, when a mechanical aid is used, the human device to which it corresponds acts only indirectly and through the agency of the mechanical aid in order to perform the work which it formerly performed directly by itself. It is unnecsary and indeed not possible for the sole of a stilt walker to make contact with the ground, and contact is made only indirectly through the agency of the base of the stilt. It is unnecessary, whenever any mechanical aid is used, for the corresponding human device to do the work it would do without its aid, and it would, of course, be useless making the mechanical aid if the human device still had to do the work. When walking, the body is propelled forward by a backward thrust on the ground by the foot, which according to elementary dynamics becomes a thrust forward on the foot by the ground. When using stilts, the foot placed in the stirrup still performs much the same action to propel the body forward, but the foot thrusts on the stirrup and not on the ground. But the thrust is transmitted by the leg of the stilt to its base and finally to the ground. The base gives a backward thrust on the ground, and the ground then gives a forward thrust to propel the stilt walker. The thrust of the foot on the stirrup is transferred to the opposite end of the part of the stilt below the foot, in accordance with the transferring Rule stated above; and it is evident therefore

that an action as well as a device can be transferred from one end of a part to its opposite end.

Chapter 53

THE TRAVOIS AND IRISH SLIDE CAR

THE travois is a primitive type of cart used by the North American Indians. It consists of two poles joined at their ends, two ends being free. The contrivance somewhat resembles the letter A, the top of the A resting on the horse's back, and the open ends trailing on the ground behind the animal. The Indians often after striking camp make a travois from two tent poles. By tying cross bars to the legs of the travois, baggage and women and children can be carried on the primitive cart so formed.

The two ends of the travois which trail on the ground bear part of the load which otherwise might have to be borne entirely on the back of the horse, the proportion of the load borne by the ends of the travois depending on the distance of the load from the ends. If the load is placed well back, most of the weight is borne by the two legs of the travois; and the rear legs of the animal are then almost relieved of the work of bearing the weight of the load.

The two legs of the travois form a rudimentary pair of artificial legs which partly replace the animal's legs in the work of bearing the weight of the load. They cannot be made to perform even the most rudimentary walking motions, like those performed by stilts or by the spokes of the wheels of a vehicle, but are dragged along the ground as one might imagine the rear legs of an animal might have to be dragged by the animal if they were broken.

Since the legs of the travois cannot be made to move in any way to help in propelling the load forward, the animal's hind legs must thrust against the ground to provide the motive power. The ends of the travois help merely in bearing the weight of the load, and do not help or take part in propelling it.

The use of a travois gives the advantage of relieving the

animal of most of the weight of the load, and the animal is therefore more free to pull the load forward than if it had the double task of bearing the weight of the load and of pulling it forward. Since there is less weight on the animal's back when part of the load is carried by the legs of the travois, there is less wear and tear on the animal's hooves, the extra wear and tear occasioned by the weight of the load being taken mainly by the ends of the travois which trail on the ground. These become worn after some use, and must be replaced or new poles must be used. The ends which trail on the ground clearly correspond to the hooves of the animal, for they perform somewhat similar functions in bearing part of the weight of the load and in taking the wear and tear occasioned by the weight of the load. Like the hooves they make contact with the ground. They also relieve the hooves of the wear and tear which would have to be taken by the hooves if the load were placed directly and wholly on the horse's back. Like the hooves, they must be repaired or renewed. They have, however, not the property possessed by the hooves of being able to repair themselves.

The legs of the travois are directly behind the rear legs of the animal, each leg of the travois being behind one of the rear legs of the animal. It is evident the right leg of the travois corresponds to the right rear leg of the animal, and the left leg of the travois to the left rear leg of the animal.

A primitive form of the Irish slide car resembles the North American travois, but is more in the form of the letter H than the letter A, being open at both ends, the front ends being fastened to the sides of the horse after the manner of the shafts of a wheeled cart. In its simplest form it consists of two poles, or shafts, connected by crossbars, and fitted with a cage or frame to hold a basket or other container. To prevent the ends of the poles wearing as they trail along the ground, they are usually fitted with wooden runners which may be fastened so that they are nearly horizontal, or be fastened to lie nearly along the lengths of the poles. This primitive type of Irish slide car is used mainly in hilly country for transporting peats, ferns, and hay, from high grounds

to lower levels; and for these purposes is more useful than a wheeled cart, which would need a drag when descending and would be heavy to haul up hill.[1] The slide car is very light, and can easily be hauled up hill, and its sledge action when descending is preferable to the action of a cart fitted with a drag.

Correspondence of the poles to the rear legs of the animal is slightly more close in the case of the slide car than in that of the travois. The poles instead of branching out from a point on the animal's back, are nearly parallel; and therefore each pole for the whole of its length is more directly behind the leg to which it corresponds. Also, the runners correspond more closely to the hooves, since they are separate parts. The runners besides corresponding to the hooves correspond to the horse's shoes, if any are fitted. A horse shoe is an artificial aid to the horse's locomotive machinery, raising it to a height above the ground equal to the thickness of the shoe, preventing wear of the hoof, and taking the wear that otherwise would be taken by the hoof. That the shoe corresponds to the end of the hoof is evident from its position, the shoe being situated exactly at the end of the hoof. It is evident also from its shape, the shoe following exactly the form of the end of the hoof and fitting snugly against and into it. Indeed, to make correspondence as exact as possible, the shoe is fitted when red hot and burns its shape into the hoof. A runner is not situated near the hoof, but is transferred to the end of the pole which itself corresponds to the horse's hind leg. Like the shoe, the runner must be as good a fit as possible on the pole. There is only the most rudimentary resemblance in shape between the shoe and the runner; but correspondence of functions makes it evident that the runner corresponds to the shoe.

[1] Dr. Cyril Fox, Sleds, Carts and Waggons, *Antiquity*, Vol. V, 1931; Alfred C. Haddon, *The Study of Man*.

CHAPTER 54

THE HOBBY HORSE

THE hobby horse, forerunner of the modern bicycle, first made its appearance about the beginning of the nineteenth century. It consisted of two wheels of about equal sizes, placed one in front of the other, and connected by a horizontal bar, or backbone, on which the rider sat astride. The rider steered by means of a handle fastened to the front wheel, which he grasped by both hands. He propelled himself and the machine by pushing on the ground with his feet.

When seated on the hobby horse, the rider's feet could comfortably reach the ground and prevent him falling sideways. When moving, the feet performed modified walking or running movements taking long strides, the impulses to propel the rider and machine being given by thrusts from the toes of the feet as they came alternately near the back wheel.

The length of the stride was approximately equal to the distance between the points of contact of the wheels with the ground. The foremost foot was placed on the ground below the front hub, and remained on the ground until the toes came about under the rear hub; and as the foot went to the rear the toes thrust on the ground to propel the machine and rider.

The weight of the rider was borne almost entirely by the machine; and only a small proportion of his weight was borne by the feet as they were placed on the ground; the spokes in turn as they came to the lowest positions taking nearly all the weight. Since each spoke of each wheel in turn performed leg actions, as described in a previous chapter, and the parts of the rims near them performed foot actions, the hobby horse was a contrivance which enabled the rider to proceed over the ground with a quick walking or running

action, with a stride about equal in length to the distance between the hubs.

Because the rider's weight was borne almost entirely by the machine, his legs were freed from the work of supporting his weight, and could be used mainly for the work of propelling himself and the machine. On smooth, hard, level ground the advantages of having no weight on his legs and being free to use them to give the impulses for progression enabled fairly quick progress to be made. On a downward slope considerable advantages were gained, because the weight of the rider being borne by the machine and no impulses being required from the feet, the rider could remain seated on the machine which ran forward under its own momentum until it came to rest at the bottom of the hill.

A runner who is descending a hill may not need to propel himself forward, or hold himself back, if the hill is of a certain steepness; but he is under the necessity of placing his legs alternately in front of himself to prevent himself falling to the ground. The work of propelling his body is done by the force of gravity; but the runner must exert himself strenuously to move his legs so that his body shall be supported at a constant height above the ground as he moves down the hill. If the hill is so steep that he cannot place his legs in position quickly enough to hold up his body, he must check his motion by thrusting against the ground with the foot which is foremost.

When descending a hill astride a hobby horse, the rider is not under the necessity of supporting his weight, and the actions of placing the feet alternately in front of each other are performed automatically by the artificial legs or spokes of the wheels. The rider can therefore keep his feet off the ground and allow the machine to run freely down the hill. The action of placing one spoke in front of another can be carried out at a great speed by the wheels, and so there is no need to check the speed of the rider and machine; and the speed that can be attained by a rider descending a hill with the aid of a hobby horse is much greater than can be obtained by means of the unaided legs. When ascending a

hill, if it is at all steep, the advantage of having the weight of the body carried by the machine does not outweigh the disadvantage of having to propel the machine as well as the rider; and usually the rider must dismount and push the machine to the top of the hill before he can ride again.

The balance of the hobby horse and rider is kept in much the same way as when a person is running. When a person stands, a base is formed by the soles of his feet or shoes; and to keep upright he must stand so that the centre of gravity of his body is above this base. The shape and position of the base can be easily seen if a chalk line is drawn round the soles enclosing the feet, or a cord is tied tightly round the soles passing round the outsides of the toes and heels. A small child finds difficulty in keeping his centre of gravity above this base, but gradually discovers how to do it; and eventually can maintain his balance without consciously trying to do so. When a person stands he is continually using his locomotive muscles to keep the centre of gravity of his body above the base, the actions being performed almost unconsciously. If the centre of gravity is not kept above the base, the person of course will fall down.

When walking, the centre of gravity of the body is moved forward in more or less a straight line. In order to preserve balance, it must be kept above the base formed at any time by the soles of the feet or shoes. Since the walker is moving forward, the base must continually be moved forward and be changed in shape, but the centre of gravity must be kept above the base.

When standing, the feet are usually placed side by side, and a small distance apart so as to form as large a base as can conveniently be made. When walking the feet are not kept so far apart sideways, and move more nearly in a single track. The width of the base at any moment is therefore less as a rule than when standing, and the walker would be more liable to fall sideways than if he stood still; but because of the tendency of a mass to move in a straight line the width of the base can be made less with safety than when standing still. If a walker feels he is going to fall to one side

he places the foot nearer that side a little farther outwards to make his base lie under the centre of gravity.

When running, the feet move more nearly in a single track than when walking; but owing to the greater speed at which the centre of gravity is moved balance can be easily kept by placing one foot a little outwards towards the side the runner feels he is falling and so bringing the centre of gravity again within the base. In practice the foot is placed a little too far to one side and the centre of gravity therefore begins to fall to the other side. This tendency is then corrected by placing the other foot a little too much to that side. This process is continued during the whole time the runner is moving.

In order to turn a corner, the centre of gravity must be made to fall towards the direction in which the runner wishes to go. He therefore places a foot outwards in the opposite direction so that the base is well on the outside of the curve he wishes to describe. The body then has a tendency to fall towards the inside of the corner, and the runner can then round the corner. For example, if a runner wishes to turn to the left, he places his right foot outwards and brings his left foot near to it with his next step. His centre of gravity then falls to the left of the base and the runner's body begins to fall to the left. The centre of gravity is then forced to describe a curve towards the left. When the turn has been made, the runner places his feet, as nearly as he can, again under the straight line which the centre of gravity will then describe.

When riding a hobby horse, the balance is kept according to the principles by which the balance of a person is kept when standing still, walking, or running. When the rider sits astride and before he moves forward, he must form a base with his feet and the artificial feet of the machine, within which the centre of gravity of the machine and rider can fall. This base is made by the feet and the points of contact of the wheels with the ground. As long as the centre of gravity of rider and machine falls within the base made by chalking a line or drawing a cord tightly round the points of contact

of the wheels and feet with the ground, balance will be maintained. If the rider lifts one foot off the ground, the base is then formed only by the triangular area which could be shown by a line drawn round the points of contact of the wheels and one foot. Since the rider sits nearly over the line between the two wheels, he is in some danger of falling to the side on which no foot is placed.

When moving slowly, the feet are placed on the ground nearer the machine. The base therefore is narrower. But if the rider feels he is falling to one side he places the foot which is on that side a little farther outwards, thus increasing the width of the base on that side. By exerting some pressure with his toe he can throw his centre of gravity a little more to the other side and so correct the tendency to fall.

When moving at speed, the feet are not used to any extent to form the base; and the balance is kept almost entirely by moving the front spokes by means of the handle held by the hands. As in running, the track is almost a single line, one wheel moving nearly in the track made by the other. The centre of gravity of machine and rider will move forward in a straight line unless prevented from doing so. But because of the unevenness of the ground, and because the machine will not run exactly in a straight line, the centre of gravity will proceed in a slightly different direction from that in which the machine is moving; and in a few moments the centre of gravity would not be over the very narrow base formed by the line joining the points of ground contact of the two wheels. But when the rider feels he is falling to one side he immediately steers towards that side. This brings the weight to the opposite side to which he was about to fall, and he then begins to fall to the other side. He then immediately steers towards that side, causing himself to begin to fall to the other side. These movements are repeated, the rider steering first to one side and then to the other. When learning to keep balance, the rider usually steers the machine too much to the side to which he feels he is falling. There is therefore too much of a tendency to

fall to the other side, which the rider then tries to correct by steering too far to that side. But as he becomes more expert, he learns to steer only slightly and sufficiently to the side to which he feels he is going to fall; and after a time can perform the correcting movements so nicely that the machine appears to be moving almost in a straight line with the rear wheel moving almost in the track of the front wheel. But if the tracks made by a bicycle on a road or other surface are examined, it will be seen that the front wheel's track is always at first to one side and then to the other of that made by the back wheel. As a child after learning to keep his balance performs the movements for balancing almost unconsciously, so, after learning to ride, a cyclist similarly performs the movements of balancing almost unconsciously.

The ways balance is maintained by a person standing or moving and by a person when on a bicycle are of course well known, and are described at length in books on mechanics and on the theory of the bicycle. They have been briefly stated again here, merely to help to show that when mechanical contrivances are fitted to the body, the principles by which balance is maintained are the same as those by which it is maintained when no mechanical contrivances are used. If the theory of this work is correct that the use of mechanical contrivances introduces no new principles, then it can be expected that the ways a person keeps his balance when say on a bicycle will be similar to the ways he keeps his balance when walking or running.

When steering a bicycle, the front spokes are placed first to one side of the machine and rider and then to the other; and instead of the feet performing this movement, as when running or walking, the artificial legs, formed by the spokes, perform this movement. The spokes therefore relieve the feet of this task of directly making contact with the ground to preserve balance; and are clearly rudimentary forms of the devices formed by a runner's legs for preserving balance. The spokes also take the weight of the machine and rider, and therefore correspond to the devices formed by the legs of a runner to take the weight of the runner.

If, as a rider was moving on a hobby horse, the machine could be made invisible, the rider would seem to be progressing in a manner somewhat resembling that in which a runner moves. The locomotive actions however would be modified, some considerably, some hardly at all. The actions of the legs would not be much different. They would be placed alternately in front of each other as in running. The rider would seem to be running daintily on his toes, and would seem to be taking very long strides. As each leg came back, the knee would be slightly bent as in running. The rider would seem to be "riding on air". Actually he would be riding on a very heavy and clumsy machine.

When walking the arms are moved alternately with the legs. As the left leg goes forward the right arm goes forward; as the left leg comes back the right arm comes back. Similarly the right leg and left arm are moved together forwards and backwards. When running the arm actions are modified, and the arms are not lifted so high as when walking but are kept about waist high, and moved slightly across the body instead of upwards and downwards. When riding on a hobby horse, the arms do not make any movements to correspond with the forward and backward movements of the legs, except for very slight movements as the machine is steered, and are kept almost stationary on the steering handle, but at about the height of the waist. On no type of bicycle at present in use can the hands be moved in time with the legs; and no doubt this is one cause of the difference in the movements and actions of a runner and a cyclist. In the pioneering days, some machines were made in which the hands operated levers to propel the machines, and performed forward and backward movements as in running. Sometimes hand levers and foot levers were used on the same machine. Baron de Drais, a pioneer of the bicycle, made a machine which was driven by hand levers assisted by the thrust of the feet on the ground. Many types of tricycles have been made, and many are used today, principally by invalids, in which the propelling impulses are given by the hands and not by the feet. The "Road-sculler" and "Oarsman"

tricycles were designed so that as many muscles of the legs, back, chest, and arms, as possible could be used.[1] On the bicycles in use today, the principle that the arms should be moved to help progress and preserve balance has been largely neglected; and no means can yet be seen of usefully making the arms move. Perhaps the bicycle of the future will need movements of the arms as well as the legs. Its form however cannot yet be seen.

[1] A. Sharp, B.Sc., *Bicycles and Tricycles.*

CHAPTER 55

THE BICYCLE

THE impulses to propel the rider of a hobby horse were given by the feet making contact with the ground and pushing the machine and rider forward, and no means were provided for making the spokes of the wheels give the impulses. But means were soon discovered of relieving the feet of the tasks of making contact with the ground and directly giving the impulses. Pedals were fitted for the feet to tread upon, and the impulses instead of being directly given to the ground were given to the pedals which transmitted them by means of cranks, cogs, and other devices, to the spokes or mechanical legs which then transmitted them to the rims and tyres which finally transmitted them to the ground.

The weight of the rider and machine was borne by the spokes; but the weight of the rider was not taken altogether off the legs at all times, for as each foot pressed on its pedal, the rider's weight was partly placed on the pedal and his leg then bore part of the weight of the body. When running down hill, however, the rider could take his feet off the pedals, and his feet could be entirely relieved of the need for supporting the weight of the body; and the weight of the machine and rider was then borne by the spokes, which automatically performed running actions, one spoke being placed in front of another as the machine ran forward.

The Ordinary bicycle, or penny-farthing bicycle as it was popularly called, first appeared about 1870. Its essential features were a large front wheel and a small rear wheel joined by an iron rod or tube which curved over the front wheel to the hub of the rear wheel. Cranks and pedals without gearing were fitted to the front wheel, which revolved once for each revolution of the cranks. Handle bars were fitted to the front wheel, by means of which the machine and

rider were steered and balanced. In the early models the diameter of the front wheel was usually between 40 and 48 inches, and that of the smaller wheel about 16 inches. Later models sometimes had a front wheel five feet or more in height and a rear wheel with a diameter as small as 12 inches.

The fitting of locomotive aids to the machinery of the body although it gives advantages for certain purposes is accompanied by corresponding disadvantages; and probably no absolute advantage unaccompanied by a disadvantage can be obtained (Cp. Rule 6). The fitting of an Ordinary bicycle to the body allows the length of the stride to be increased; but the machine as well as the rider has to be propelled, and the force to propel both must be provided by the rider. The rider is raised above the ground, and his feet can remain dry and clean when passing over wet and dirty surfaces; but if he loses his balance he has farther to fall than if he falls when running. A greater speed can be attained with the help of an Ordinary bicycle than is possible without its help; but the rider is at the short end of a lever when pedalling, and if the wind or the incline is against him, progress becomes harder than when running or walking, and frequently the rider is forced to dismount and push the machine.

A bicycle it seems therefore is a contrivance which when fitted to the body gives the locomotive apparatus of the body certain advantages for certain purposes. By means of the mechanical aids provided by a bicycle the person fitted with them can take longer strides. The legs are not required to bear the weight of the body; but they are not released completely from the need for carrying the weight of the body, because as a foot presses on a pedal the weight of the body is partly carried by the leg pressing indirectly on the ground through the agency of the spokes. But when the cranks are vertical, the weight of the body is borne almost entirely by the machine, and the rider is then sitting on the machine, and little weight is put on the legs.

The modern bicycle with both wheels of equal sizes, when it made its appearance was called a "safety" bicycle,

because there was less danger on meeting with an obstruction of being thrown over the handle bars than when riding an Ordinary bicycle. On the Ordinary bicycle, the rider sits almost over the larger front wheel, and if the bicycle is suddenly stopped, the rider is likely to be pitched over the front wheel; but on the safety bicycle the rider is lower and his position is well behind the front wheel and unless he is very suddenly stopped at considerable speed he is in little danger of being pitched over the handle bars.

The pedals and cranks of a safety machine are not rigidly fastened to either of the hubs, but are connected to the hub of the rear wheel by means of sprockets and a chain. The use of sprockets and a chain allows the cranks and rear hub to revolve at different rates; and by suitably choosing the number of teeth on the crank and rear hub sprockets the rear wheel can be made to revolve at any desired speed relative to the crank shaft. The length of the stride can therefore be made of any desired length.

When using a single-geared bicycle, the length of the stride cannot be varied, and the rider must take a stride of the same length whether running on the level, up hill, or down hill. This is an inconvenience, for a runner varies the length of his stride according to his speed and the gradient, and it is equally desirable that a cyclist should vary the length of his stride according to his speed and the gradient and the wind conditions. A runner when going up hill shortens his stride, and when going down hill lengthens it. Indeed, he varies the length of his stride with each variation of speed and gradient. When using a three-speed bicycle, the rider has a choice of three different gears, and can change the gearing to suit his speed and the gradient. By using the lowest gear he can take short strides and so surmount fairly steep gradients. He can change to middle gear to travel on the level or against the wind or up a slight incline. To travel with the wind on the level or down hill he can change to top gear, and so take longer strides.

Most bicycles are now fitted with a free wheel device which allows the cyclist to sit on his machine as it moves

without pedalling. When the rider and machine are moving under their own momentum or being pulled down a gradient by gravity there is no need to exert any thrusts on the pedals, and since the rider is supported by the spokes which automatically place themselves under him to bear his weight and that of the machine, he need merely sit on the machine and steer it.

When the rider of a hobby horse wishes to slow down or stop, he must check his motion in much the same way as a runner checks his motion, by reversing the means by which he propels himself. To propel himself the runner or rider thrusts against the ground with his rear foot: to check himself he thrusts against the ground with his front foot. Usually several thrusts must be given by the feet, each foot as it goes to the forward position thrusting against the ground.

In order to stop himself on the level or when running down hill a runner reverses the direction of the thrusts which he gives to propel himself forward; and as each foot is placed in front he thrusts against the ground, gradually bringing himself to rest. To stop himself on the level or when going down hill the cyclist similarly must cause the spokes to exert a forward thrust on the ground so that the ground can exert a backward thrust to stop the movement of the machine. The spokes can be made to exert forward thrusts when the machine is a fixed-gear machine, if the rider presses on the pedals as they rise, instead of pressing on them as they decend. This method of stopping progress is usually effective but is not always convenient, and is difficult if the machine is travelling at speed. Some machines are fitted with a "back-pedalling" device, and when the rider presses back on the pedals he makes a brake act on the back wheel and causes the spokes to exert forward thrusts on the ground. Most bicycles however have brakes fitted to one or both wheels which are operated by the hands. To stop the machine the rider clenches his hand which encloses the handle bar grip and brake lever, and the brake acts on the tyre or rim and causes the spokes to thrust forwards. When a runner wishes to stop, he similarly clenches his hands as he thrusts

forwards with his feet. When he stops suddenly, the clenching movement of the hands is more pronounced than when he stops gradually, and similarly when a cyclist stops suddenly he clenches the brakes and handle bar grips harder than when he stops gradually.

CHAPTER 56

THE WHEEL

IT has been shown that the locomotive spokes of a wheel are mechanical extensions of the legs of a person or animal. It will now be shown that the hub and spokes of a wheel also reproduce the hub and spokes of the hand or foot.

The human prototypes of the hub and spokes of a wheel can be seen if the hand is made flat and the fingers are opened. The fingers then radiate from a hub formed by the palm; but as they are closed, the centre of the wheel approaches the wrist, and the hub is formed nearer the wrist. In a skeleton of the hand and wrist, the fingers radiate from the wrist; and the mass of wrist or carpus bones forms the hub, or nave, of the wheel. Each spoke is formed by a metacarpal bone and phalanges of a finger.

The human spokes can be revolved round the axle of the wrist either in the plane of the hand or in a direction at right angles to the plane of the hand. The movement in the plane of the hand can be seen if the forearm and palm are placed on a table, when it will be found the hand and fingers can be revolved or turned round the axle of the wrist through about a right angle. The movement at right angles to the axle of the wrist can be seen if the forearm is held in a vertical position. The hand can then be turned from a horizontal position in front of the arm with the back of the hand uppermost to a horizontal position behind the arm with the palm uppermost. The limit of this movement is about two right angles.

When a person walks on his hands and knees, the palms of the hands and insides of the fingers are placed on the ground. As he moves forward the forearm revolves round the wrist joint or, what is the same thing, the hand revolves

round the wrist joint, in a direction at right angles to the plane of the hand. This may be called a movement of revolution round the wrist. A turning movement of the hand occurs when the person moves to the right or left, the hand then being turned in its own plane to the right or left. Each hand therefore has a movement of revolution at right angles to its plane round the wrist joint, and at intervals a turning movement in its own plane round the wrist joint.

The wheel of the hand is therefore laid flat on the ground when a person walks on his hands and knees; and is in a horizontal plane and not in a vertical plane. A mechanical wheel however is upright, and rests on its rim in a vertical plane; and compared with the human wheel is turned through a right angle (Rule 10). The wheel of the hand can be turned through a right angle so that it is in a vertical plane; but progression is not easy with the wheel in this position, for the weight of the body then rests on the edge of the palm and little finger which form the rim of the human wheel. If the hand were placed in a vertical plane, as the person moved the hand would revolve so that the spokes of the fingers pointed downwards and the weight of the body would be placed on the vertical spokes of the fingers. The side of the hand and the fingers of a human being are not strong enough to take the weight of the body, and the human wheel cannot conveniently be used if placed in a vertical plane. The rim and spokes of a mechanical wheel however can be made much stronger than their human counterparts, and the mechanical wheel can therefore be placed and used in a vertical plane.

The foot is constructed on the same principles as the hand, the hands and feet of a creature being similar types of limbs. The remarks about the locomotive contrivances and actions of the hand apply therefore also to the foot, the spokes of the foot being formed by the metatarsal bones and phalanges of the toes, and the hub by the tarsus or ankle bones.

Normally a person walks on his feet, or hind limbs, and the wheels of his body are formed mainly by his feet. A human being may therefore be said to be a two-wheeled

creature; a bird a two-wheeled creature; a quadruped a four-wheeled creature; an insect a six-wheeled creature; and so on.

A human wheel has five spokes, since the foot has five toes, all of which form spokes for locomotion. The human spokes are kept nearly parallel to each other as a person walks or runs. The number of spokes of a wheel varies in different creatures. Some birds have three spokes, some two; and the spokes of the foot of a bird are not parallel, but diverge from the hub, after the manner in which the spokes of a mechanical wheel diverge from the hub. A horse has only one spoke in each of its four wheels, since each foot has only one toe, the hoof being a modified middle nail. Cows have two spokes in each wheel; for their hooves are cloven and form two spokes, each part of the hoof being a modified toe. A camel or a rhinoceros has three spokes in each wheel, a hippopotamus four spokes; and an elephant five spokes; and so on. Toes which are not directly used for locomotion can be seen on many creatures. The spur on the leg of a bird, for example, is a toe which is not used for locomotion.

When a man stands, the metatarsal bones and phalanges of his foot are horizontal and on the ground; but when a horse stands, its metatarsal bones and phalanges are vertical. The metatarsal bones and phalanges are greatly elongated in the horse, and the horse stands on the point of its greatly thickened middle toe which is encased in the hoof which corresponds with the human nail, and its toe is the only part of the foot that rests on the ground. Compared with man's bones, the metatarsal bones and phalanges of a horse are turned through a right angle (Rule 10); and the horse has a vertical spoke. The wheel of the horse is thus not laid flat on the ground, but runs in a vertical plane.

The spokes of the hand cannot revolve through more than about two right angles round the axle of the wrist in a direction at right angles to the plane of the palm of the hand. The spokes of the foot can revolve through only a small angle round the axle of the ankle; but when a person runs they can revolve through about two right angles round the thigh bone joint, this larger movement of rotation being allowed

by the bending of the ankle and knee and thigh joints. The locomotive spokes of a mechanical wheel similarly do not revolve through more than two right angles. Indeed they usually move as locomotive spokes only through a small angle before becoming struts or stays. The spokes of gear wheels probably do not revolve through more than one right angle at most; and the spokes or teeth or cogs of a watch or clock wheel probably never revolve through more than a very small angle, as will now be shown.

Much can be learnt about the principles of wheels from a study of the train of wheels in a clock or watch. There are many toothed wheels in a clock or watch. Each toothed wheel has many teeth or cogs; but only a few of them at any moment are actively engaged with the teeth or cogs of another wheel. Most of the cogs are for much of the time simply passengers, doing nothing at all, except perhaps by their weights helping to preserve the balance of the wheel. Each wheel therefore consists essentially and for all practical purposes of a hub and axle and a very few teeth or spokes radiating from the hub or axle of the wheel towards the wheel with which it is engaged. The other teeth or spokes need not be considered, for they do not do anything, and cannot be regarded as essential parts of the wheel. Teeth, of course, must be provided all round the circumference, but only so that at intervals they can become active and become engaged with other teeth. They act as teeth or fingers only during the revolution of the wheel through a very small angle, while in mesh with the fingers or teeth of another wheel, and then go out of use and cease to be active parts of the mechanism of the clock or watch until they again come into contact with the teeth or cogs of the other wheel.

A study of clocks and watches will not be made in this work; but, in passing, a few things can be noticed about their mechanisms.

On spindles with toothed wheels, there are usually two toothed wheels; a large one with many teeth, and a small one with few teeth. If only active parts of the wheels are considered, it can be seen that each spindle with two toothed

wheels really consists of a large hand and a small hand, each having say two fingers formed by the cogs or teeth in mesh with the cogs or teeth of another wheel. (The hand is formed by the part of the wheel which joins the hub or axle to the two fingers or teeth. The hand as a rule is not distinguishable as a separate device; and if the wheel is solid, it is formed merely by the part of the metal which joins the hub or axle to the active teeth.) Each spindle therefore has a large hand and a small hand, and on the last spindle a large hand and a small hand appear on the face of the clock as the minute and hour hand, and show the time.

The movements of the minute and hour hands of a watch originate from actions of the fingers as they wind the watch. The winding device is formed by the thumb and forefinger, acting on the cogged head of a spindle. As the thumb and forefinger wind the watch, a device formed by the forefinger moves to and fro round an axle formed at the main knuckle of the forefinger; and this device is somewhat similar in appearance and actions to the hair-spring wheel of a watch, the human prototype of the hair-spring wheel being this curved device, which is formed by the three joints of the forefinger as they oscillate round the axis where the forefinger and hand join. The other three fingers usually move with the forefinger; but it seems the human hair-spring wheel is formed mainly by the forefinger.

The main knuckle of the forefinger, or knuckle nearest the hand, is kept stationary when winding a watch, but when winding a clock oscillates in an arc of a circle round the axis of the winding key, and has a type of pendulum movement in the plane of its motion, round the axis of the key. Possibly the human prototype of the pendulum is the contrivance formed by the knuckle of the forefinger, or by the hand itself, the knuckle or hand corresponding to the bob of the pendulum. But the author is not sure of this, and cannot state it certainly. In some clocks instead of a hair-spring or pendulum, there is a heavy weight suspended by a fine wire. This weight and wire are almost certainly copies of the contrivance formed by the hand and forearm when winding a

clock, the weight corresponding to the hand and the torsion wire to the forearm; and the human contrivance of the forearm is, it can be noticed, at right angles to the face of the clock and therefore at right angles to the wire.

All toothed wheels, such as those in gear boxes and in clocks and watches, it seems, are mechanical copies or extensions of the wheels of the hands or feet, the cogs or teeth corresponding to the cogs or teeth formed by the fingers, the hub corresponding to the palm or to the wrist bones. The tooth does not form a spoke, but forms merely the end of a spoke, the spoke extending from the axle to the end of the tooth. Spokes are seldom separate contrivances in gear wheels, and are usually united by the metal of the wheel.

A gear wheel seldom has more than three or four active teeth, for all those not in mesh with the teeth of other wheels are inactive. Further, the spokes or teeth seldom move through more than a small arc, and never make a complete revolution while in mesh with other spokes or teeth. When not in mesh with other wheels they do not of course form spokes or teeth.

Having seen that there are few real or active spokes or teeth in a gear wheel, and that they do not move round the axle through more than a small angle, it can now be seen that only a few of the spokes of a vehicle's wheel are locomotive spokes at any moment; and that therefore a wheel has only a few active spokes, the rest forming merely struts or stays to help to keep the shape of the wheel.

Consider for example a modern bicycle wheel. This is a suspension wheel, and the weight of the rider and machine does not rest on the lower spokes but is suspended from some of the upper spokes. The lower ones do not form locomotive spokes, and act mainly as stays to keep the shape of the wheel. At most, therefore, only half the spokes at any time are actively locomotive spokes, and none make a complete revolution, and can be locomotive spokes for no more than a revolution through two right angles, after which they become stays.

Further, a bicycle wheel has two distinct and separate sets

of spokes. One set joins the rim to the right hand side of the hub, the other joins the rim to the left hand side of the hub. Possibly the right hand ones are mechanical extensions of the spokes of the rider's right hand, and the left hand ones mechanical extensions of his left hand. If this is so, then the locomotive spokes of each of the rider's hands are represented at any moment at most by no more than a quarter of the number of the spokes of the mechanical wheel.

The number of locomotive spokes, however, is perhaps decided by the number of spokes from the hub to the portion of the tyre which is in contact with the ground. As the tyre is deflated, the number of locomotive spokes increases; but when the tyre is properly inflated, the number of locomotive spokes, or spokes actively engaged in locomotive movements, may not exceed the number of spokes of the hands or feet. Since, in a suspension wheel the locomotive spokes become reversed, in the bicycle wheel the spokes opposite to those connected to the portion of the tyre in contact with the ground become the locomotive spokes.

Since the bicycle nowadays is suspended from the uppermost spokes, the spokes of the mechanical hand point upwards. In a motor car with wheels with wire spokes, similarly, since the weight of the motor car is suspended from the uppermost spokes, the mechanical hand points upwards. The mechanical hand points downwards when the spokes are solid and the weight of the vehicle rests on them; and the direction of the hand is then reversed (Rule 11).

The mechanical hand of a vehicle wheel thus points upwards or downwards, the direction of the hand depending on the type of wheel. The mechanical hand formed by a gear wheel or toothed wheel always points in one direction, and does not revolve through more than a small angle round the axle. This is much the same as when a creature walks, for the foot always points forwards, but is moved slightly to the left or right, as direction is changed. The principles of the mechanical wheel are therefore similar to those of the human wheel formed by the foot.

The human fingers are webbed for a small distance, the

webbing being where the skin joins two fingers together near the palm. When the hub is formed at the wrist, the human spokes are webbed by the skin, muscles, and other parts of the main part of the hand. The spokes of the wheels of some creatures are fully webbed. Those of a duck, for example, are webbed as far as the points. Webbed mechanical wheels are used on many vehicles, the webbing being formed sometimes by a disk covering the spokes. If the theory that the mechanical wheel was at first a solid wheel is correct, then the webbed wheel preceded the spoked wheel.

A walking stick, besides being a mechanical extension for an arm or leg is also a type of spoke, and forms an extension for the spokes of the hand. If the head is in the form of a knob it is held in the hand against the palm; and the hub is formed by the palm; but the axle is formed by the wrist joint if the stick is held firmly, since the walking stick is moved round the wrist joint. But if it is loosely held, the axle is partly formed at the palm, the knob fitting into a kind of ball joint formed by the palm and fingers surrounding the knob.

When a walking stick with a knobbed head is held firmly in the hand, the axle is not at the centre of the palm; and the hand then forms a type of cam, and the knob of the stick moves eccentrically round the axis of the wrist.

The rim of the hand or foot is not mechanized in the walking stick machine; for the walking stick has no curved tyre or rim at its end; and is a rimless spoke. The stilt also has no rim, and the user walks as if on the stumps of his feet, and not with the easier and more flexible movements allowed by the use of a mechanical extension of the rim or tyre of the foot.

Chapter 57

THE BICYCLE FRAME

As the rider sits on the bicycle, his head and arms are nearly over the handle bars, steering head, front forks, and front wheel. The human parts are given mechanical extensions by means of these mechanical parts.

The handle bars copy the human handle bars formed by the rider's arms; but the human contrivance is concave to the front and the mechanical contrivance is concave to the rear; and one contrivance compared with the other is reversed (Rule 11). The grips of the handle bars are formed by the handle bar ends which are usually covered with rubber. They form mechanical extensions for the barrels of the hands, and since the tubes are hollow, the hollows of the hands are reproduced. The rubber forms a type of artificial skin for the interior surfaces of the hands and for the exterior surfaces of the ends of the handle bars. The pressure of the hands causes the mechanical barrels and human barrels to fit well and correspond closely in shapes. The chequerings of the palms and insides of the fingers are reproduced very crudely and imperfectly by the treads or markings on the surfaces of the rubber grips, but the riflings are not reproduced mechanically and are formed only by the fingers.

The rider's head is reproduced, very crudely and indistinctly, by the steering head. This sometimes projects slightly above the middle of the handle bars. Various types of mechanical heads are found on bicycles. The original head of the velocipede, for example, was known as the sockethead.[1]

The steering column and tube reproduce the upper arm, or humerus; the front forks the two bones of the lower arm, the radius and ulna. As was explained in the last chapter, the

[1] *The Badminton Library*, Cycling.

hub, or nave, of the wheel corresponds to the wrist bones, or solid contrivance formed by the bones of the carpus; the spokes correspond to the spokes formed by the metacarpals and phalanges radiating from the axle of the wrist; and the axle corresponds to the wrist joint.

The human wheel does not lie between the two bones of the lower arm; but the mechanical wheel lies between the radius and ulna of the bicycle, because, as has been explained, the mechanical wheel compared with the human wheel is turned through a right angle.

The steering column and forks and wheel are not alongside their human counterparts, but proceed from them, much as a club proceeds from its human counterparts, which are the fist and arm. The mechanical parts are therefore in transferred positions, and it is not difficult to see how they are placed with respect to their human counterparts. The rider's hands are on the handle bars. The grips of the handle bars are within the hands, and have not been transferred away from the hands; but the mechanical counterparts of the spokes of the hands have been transferred along the handle bars to the top of the steering column, then to the lower end of the steering column, then down the forks to the axles. The reader will no doubt be able to see for himself that the mechanical extensions of the rider's upper and lower arms have been somewhat similarly transferred. The ball joints of the shoulders and hinge joints of the elbows appear in mechanical forms as the joints and bearings of the steering column and axle of the front wheel.

The two bones of the human lower arm are connected at the elbow and wrist; the two front tubes of the bicycle, which are crude mechanical copies of these human parts, are somewhat similarly connected at their ends. At their upper ends the front forks are rigidly joined. At their lower ends, the front forks are connected by the spindle of the axle; and the mechanical spokes can have certain limited movements of revolution relatively to the radius and ulna, or forks, but cannot make complete revolutions except as struts or stays.

If a line is drawn round the points of the spokes of the

fully opened fingers, it will form an arc of a circle approximately, and represent the circumference or rim of a wheel. A person when he walks on his hands and knees places the palms and insides of his fingers on the ground; when he walks upright he places the soles of his feet and insides of his toes on the ground. He does not walk or run on the points of his toes, that is on the points of his spokes; and it is the flat of his hand or foot that forms the tyre of his wheel.

The frame of the bicycle was formerly made of solid rods, but is now made from hollow tubes. A hollow tube can represent a bone of the human frame better than a solid rod can represent it, because it is hollow like the human bone. Correspondence of materials of the mechanical frame to the materials of the human frame is poor when the tubes are of steel; but the property of rigidity of the human bone is possessed by a steel tube. Features of a human bone are probably reproduced better by tubes made of wood or bamboo. The various joints of the bicycle are separated by a film of oil, in much the same way as the human joints are separated by the synovial fluid which lubricates them.

Both arms of the rider are mechanized by means of the steering column and front forks. The steering column therefore represents the humerus of the right arm and the humerus of the left arm; and the mechanical counterparts of both upper arms can be regarded as fused into a single contrivance. One fork similarly represents the radius of the right arm and the radius of the left arm, and the other the ulna of the right arm and the ulna of the left arm. The front forks are nearly similar, and the author does not know which is the radius and which the ulna of the bicycle.

The human counterparts of the back parts of the frame can now easily be known. The spokes of the back wheel are mechanical counterparts of the spokes of the feet of the rider, formed by the bones of his feet. The counterpart of the upper bone of the leg, or femur, is formed by the saddle pin and part of the back stays between the saddle pin and back forks. The two prongs of the back forks reproduce the two bones of the leg, the tibia and fibula, or more correctly,

the two tibias and the two fibulas of the legs, the forks being fused contrivances.

Until recently a step was usually fitted to the back axle. This was a projecting bolt screwed on to the back axle, usually on the left side; and was used when mounting the bicycle. The rider stood with the back wheel between his legs and his hands on the handle bars. He placed his left foot on the step and pushed off with the right foot and then lowered himself on to the saddle. A boy cyclist often gave another boy a ride on the step; and the passenger rode with his left foot on the step and his hands on the rider's shoulders. Sometimes two steps were fitted, one on each side of the axle, and the passenger then stood more comfortably with a foot on each step.

As a rider stands with his foot on the step after pushing off and is about to place himself on the saddle, the various mechanical counterparts of his frame, or skeleton, are revealed by the proximity of mechanical and human parts, for the mechanical parts of any machine are always next to or as near as possible to their human counterparts, or extend outwardly from them, unless they are in transferred positions. This rule holds good for all machines or mechanical contrivances, whether it is a bicycle, a pair of spectacles, an internal combustion engine, a weapon, an aeroplane, a submarine, a wireless set, a pen, a typewriter, a pin, a stilt, or any other mechanical machine or contrivance. If the mechanical parts are in transferred positions, their human counterparts can be discovered by application of the transferring Rules (Rules 7—11). The frame of the bicycle is almost entirely formed of mechanical counterparts of the bones of the rider, as the word "frame" shows. When therefore the rider is on the step, the mechanical counterparts of his frame are revealed by the proximity of his legs and feet to various parts of the frame of the bicycle. When his legs and feet have been transferred from the step to the pedals, they are then placed alongside different tubes, whose human counterparts then become revealed. Further, as the feet are transferred to the pedals they are moved along the sides of the two

tubes which connect the rear hub and pedal bracket, showing that these tubes are also extensions of the feet or legs. Thus, when the rider is on the step, the upper parts of his legs, the femurs, are approximately alongside the saddle pin and parts of the forks above the mudguards, revealing that these mechanical parts are derived from and copies of the femurs. The lower parts of his legs are alongside the two forks of the back wheel revealing that these forks are mechanical counterparts of the tibias and fibulas. His foot is on the step and next to the hub and axle, and the bones of his foot are alongside some of the spokes, revealing that the hub and axle are derived from the tarsus, and the spokes from the metatarsals and phalanges of the toes. The rider remains for only a few moments in this position, and then places his legs and feet in transferred positions. His legs are then placed alongside the tube from the saddle to the pedal bracket, revealing that this tube corresponds to the contrivance formed by his legs. He transfers his feet from the hub to the sides of the pedal bracket. The soles of his feet are placed on the pedals, revealing that the flat parts of the pedals are extensions of the soles of his shoes (Rules 1, 2, 3, 4, and 7). The saddle, or seat, is evidently an extension of the seat of the rider, as correspondences of names and positions show.

The ways human parts can be transferred can be seen as the rider moves from the step at the rear axle to the pedals. He transfers his legs from positions in which they are alongside the back stays, or tubes between the saddle and back wheel, to positions in which they are alongside the seat tube, which is the tube between the seat and pedal bracket. He transfers his feet from the rear hub to the pedal bracket, moving them from one end to the other of the horizontal chain stay tubes, or tubes between the rear hub and the pedal bracket (Rule 8).

The chain stays and the taut or upper part of the chain allow the actions of the legs when pedalling to be transferred from the pedal bracket to the rear axle; and the chain stays and taut part of the chain therefore probably form extensions of his legs.

The chain wheel and rear wheel sprocket are essentially contrivances to transfer the actions of the feet to the hub of the back wheel. Each toothed wheel, as has been explained, is a mechanical extension of the wheel of the foot. If the pitches of the teeth of the sprocket and of the chain were the same, all the teeth of the sprocket would be active teeth; but because of the stretching of the chain, in practice the pitches are never exactly the same, and, therefore, as is explained in books on the theory of the bicycle, only one tooth works, or at most two teeth work, in engagement with the chain links, that is the chain sprocket has only one active tooth or at most two active teeth.

The backbone of the bicycle is formed partly by the horizontal top tube. This tube is indeed a modified form of the long pole or rod or perch of the hobby horse which is called by writers on the bicycle the backbone of the hobby horse.

The front portion of the frame, it will now be shown, besides reproducing features of the arms and hands of the rider and forming mechanical extensions for them, at the same time reproduces features of his legs and feet.

To straighten the handle bars, a person sometimes stands astride the front wheel with his hands on the handle bars. In this position, mechanical counterparts of the legs and feet are approximately alongside and opposite their human counterparts. The human handle bars, formed by the rider's arms, are now concave to the rear of the bicycle and lie over and somewhat alongside the mechanical handle bars, the human contrivance being reversed compared with its position when the person is on the saddle. The human contrivance is connected to the person's legs by his backbone. The backbone of the person is represented in the bicycle by the steering column and tube. The upper parts of his legs, the femurs, are reproduced by the two front forks, each fork reproducing a femur. The lower parts of his legs are reproduced by the spokes of the wheel which happen to be nearest the ground. The soles of his feet or shoes are reproduced by the part of the tyre near the ground.

There is therefore a double representation of human parts;

for the front of the frame reproduces features of the rider's arms, and reproduces also simultaneously features of his backbone and legs. The steering column, it has been shown, forms an extension for the rider's upper arms. It can now be seen it also forms an extension of his backbone. Somewhat similarly, the front forks reproduce not only the rider's arms, they also reproduce his femurs. The spokes reproduce not only the spokes of the hand; they also simultaneously act as extensions of his lower legs. Mechanical contrivances very often correspond simultaneously to more than one human contrivance, as has often been noticed. It was shown, for example, that the knob of a club corresponds simultaneously to the fist and to the head of the wielder; and in general a part of a weapon reproduces simultaneously an offensive and a reproductive device. Human contrivances usually similarly form several contrivances at once. Thus, for example, the canal of the mouth is an induction pipe, through which air can be drawn into the body. It is also an exhaust pipe, through which heated exhaust fumes can be discharged from the body. It is also part of the alimentary or food canal. It is also a vocal aperture, and serves much the same purpose as the mouth of a musical instrument, say of a trumpet. Or again, as has been shown, the hand forms a wheel. It can also form a barrel, rifling devices, and a host of other devices.

It can now be understood how the spokes of a wheel reproduce locomotive actions of the leg, and at the same time are mechanical reproductions of the spokes of the foot. By means of the mechanical wheel of a vehicle, the lower leg and the hub and axle and spokes and tyre of the foot are combined.

The dimensions of some parts of the bicycle correspond fairly closely to the dimensions of their human counterparts: but some do not correspond very closely. The top tube corresponds fairly closely in length and diameter to the length and diameter of the human backbone. But the steering column which also corresponds to the backbone is much shorter than the human backbone. It is however about the

same length, sometimes, as the humerus, to which it also corresponds. The front forks are about the same lengths as the femurs; but longer than the radius and the ulna. The spokes are about the same lengths as the lower legs. The width of the tyre is matched by the width of the foot, if this is measured from the ground to the skin on the top of the foot. The bicycle however is an extremely crude and undeveloped contrivance, as is evident say from the fact that although the rider's legs move with almost full running actions, his hands are forced to remain nearly stationary, but they do perform some rudimentary piston actions as the wheel is steered alternately to one side and then the other.

The wheels of the bicycle unlike the legs are not side by side. When a person walks slowly his feet, or wheels, move in two separate tracks; but as speed is increased, the tracks tend to become one track; and when a person runs at full speed, he runs almost in a single track. As the bicycle is a machine to help in fast running, providing mechanical extensions for certain of the rider's locomotive contrivances, this may be one reason why the wheels are placed in line instead of being placed side by side.

The backbone of a person is not of constant length; for it has shock absorbers between each two vertebrae; and as a person walks or runs, the backbone increases or decreases slightly in length as its shock absorbers work. The steering column of an ordinary bicycle does not vary in length as the rider progresses; but the steering column of a motor bicycle may vary in length, because of shortening or lengthening actions as the shock absorbers work.

The various tubes of the frame of the bicycle are not all parallel or at right angles to each other. It may seem, at first, therefore, that parts of machines can be turned through angles other than right angles. But most and perhaps all of the tubes are combined contrivances; and it is therefore difficult to determine the position of any one contrivance with respect to another; and so the Rules which allow for the turning of parts or actions only through right angles may not be violated. Rules often appear to be violated when in fact

they are not violated. Thus, for example, it is believed that all bodies are drawn or attracted to the earth. But a balloon does not fall to the earth, and it seems at first that the belief is incorrect that all bodies are drawn to the earth. But when all the forces acting on the balloon are distinguished it can be seen that the belief is correct. Rather than introduce the difficult idea, which would lead to endless complications, that a part or an action can be turned through an angle other than a right angle, it will be better to keep the Rules as they are, until it can be proved an action or a part can be turned through an angle other than a right angle. It would be difficult to show that an action of a part of a bicycle can be turned through an angle other than a right angle, because all joints and bearings are oiled; and when a film of oil separates two parts, one part can act on the other only at right angles to it. Indeed a bicycle is oiled to ensure that actions shall not be turned through any angles except right angles. Similarly other machines, like the steam engine and internal combustion engine are oiled to ensure that actions shall be turned only through right angles.

It is well known that the division and subdivision of the right angle into degrees, minutes, and seconds, is arbitary. It is not a satisfactory method of division, as is evident from the fact that a different method is often used, the centesimal or French method, in which the right angle is divided into 100 equal parts called grades, and each grade is divided into 100 minutes, and each minute into 100 seconds. Neither of these methods finds any correspondence in or authority from nature; and the use of either method leads to endless complications. Attempts have been made to find so-called natural divisions of the right angle, one method being to use the radian, which immediately results in the mathematician having to use incommensurable numbers, like π, which cannot be expressed as whole numbers. If it cannot be proved nature divides the right angle, it will be necessary to examine the fundamental assumptions on which geometry, trigonometry, mechanics, astronomy, and other sciences in which measurements are used, have been built; and it will perhaps be seen

that a very simple geometry based merely on the use of right angles can be used. In this work, as a result of using this simple geometry and refusing to divide the right angle until some authority for so doing can be obtained from nature, it has been found possible to discover how many parts of machines and some parts of the body are situated with reference to other parts. If degrees, minutes, and seconds, are used, the human body at once presents angles and curves which cannot be expressed in any geometrical or trigonometrical system hitherto used, and the geometry of the body becomes incomprehensible.

The Rules as given in this work have not been satisfactorily formulated. Some of them indeed are contained or included in others. For example, Rule 11 is contained in Rule 10, because if a part or an action is twice turned through a right angle it becomes reversed. The Rules therefore have not been dignified with the title of laws. No doubt some reader will see how to formulate them better; and perhaps when other Rules have been discovered, a few simple laws will be formulated, and allow the study of mechanical contrivances of the body to be placed on a satisfactory basis. The Rules should therefore be regarded merely as rough and ready guides to help to show how mechanical contrivances originate and develop.

PART IV

THE MOTOR CAR

Chapter 58

THE INTERNAL COMBUSTION ENGINE

MANY of the human counterparts of the mechanisms of the internal combustion engine can be discovered without difficulty.

The engine has nostrils formed by the apertures of the carburettor through which air is drawn in. This is evident because air is breathed in through the carburettor in much the same way as it is breathed in through the nostrils of a creature; and if a cloth is placed over the carburettor's mouth or nostrils, the engine begins to splutter and cough, and will be choked if the cloth is not soon removed, in much the same way as when a hand or cloth is placed over a creature's nose it begins to splutter and cough, and will be choked if the hand or cloth is not soon removed.

The air breathed in by the engine is warmed as it passes through the carburettor and intake pipe, as it is warmed by the nostrils and wind-pipe of a creature. If a dust filtering or an air purifying device is fitted to the carburettor, the air is purified as it is drawn in, in much the same way as it is purified when it is drawn in through a creature's nostrils.

The throat of the carburettor is formed where the throttle works. This must be so, because the word throttle means throat; and when the throttle is fully open the throat is fully open, and the engine then breathes or takes in air to the greatest extent. The choke, as the name shows, is a device for constricting the throat and causing less air to be inhaled, the engine being partly choked when the choke wire or rod is operated.

The wind-pipe, or trachea, of the engine is formed by the intake pipe or inlet manifold, which is the tube or pipe leading from the carburettor's nostrils and mouth to the interior organs of the engine. (It was shown earlier that the throat and wind-pipe are reproduced by the lawn tennis racket

where the frame joins the handle. Different features of the throat and wind-pipe, however, are reproduced by the internal combustion engine and by the lawn tennis racket.)

The lungs are reproduced by all types of the engine; but reproduced differently by different types of the engine. Part of the work of the human lungs is to mix the air, or certain constituents of the air, with certain constituents of the food, the constituents of the food being brought to the lungs and distributed throughout their myriads of cells by the blood vessels and their capillaries. Since the constituents of the air and food mix in countless parts of the lungs, a kind of mist of the combined constituents is formed. That this is so is shown by a study of the actions of the air and petrol in the lungs of the engine, for the lungs of the engine reproduce features and actions of the human lungs; and we can therefore understand some of the actions of the human lungs from a study of the mechanical lungs of the engine. From the human lungs some of the mixed constituents of air and food are carried by the pulmonary veins to the heart. They are carried in the form of a fine mist, the mist being formed in the blood in which there are many other materials and substances, water being one material or substance. If the other constituents could be removed from the blood, no doubt a fine mist of the constituents used for the working of the human engine would be seen moving through the pulmonary veins, not evenly but in bursts, as the fine mist of mixed air and petrol moves along the pulmonary veins of the engine, represented by the induction pipe.

The lungs of the engine are formed by the mechanisms which mix the air and petrol and turn them into a fine mist or vapour. In early days the air was drawn over the surface of petrol or over plates or a wick soaked with petrol; but nowadays is usually drawn over a jet or several jets. The parts which form the lungs of a four-stroke engine are not easy to determine exactly; but the lungs are evidently formed between the jets and the cavity of the cylinder head, the inlet manifold pipe forming a main part of the lungs.

The lungs of a two-stroke engine are partly formed by the

cavity of the crank-case, because the petrol and oil are turned into a fine mist in the crank-case. The lungs of a two-stroke engine, therefore, since they include the crank-case cavity, are larger and more extensive than those of a four-stroke engine.

The air and petrol, after being changed chemically, are discharged through the outlet and exhaust pipes into the atmosphere. The exhaust gases are not therefore returned along the wind-pipe, or intake pipe, and discharged through the nostrils of the carburettor as they are discharged through the wind-pipe and nostrils of the human body; and the discharging tube is separately mechanized in the engine, and is not combined with the intake tube as in the human body. In the human body there is an economy of apparatus, and the wind-pipe of the human body is both an intake tube and an exhaust tube. The engine's exhaust tube evidently corresponds to and is an extension of the human exhaust pipe formed by the wind-pipe for the discharge of the spent gases into the atmosphere. The structure and materials of the intake pipe of the engine and those of its exhaust pipe are different. The exhaust pipe, for example, is made to withstand the heat and corroding effects of the exhaust fumes. The human wind-pipe has features both of an intake and of an exhaust pipe; and is also made to withstand the corroding effects of the heated exhaust fumes discharged from the body. It would not need to be made capable of withstanding the corroding effects of heated carbon dioxide gas fumes if it were merely an intake pipe.

The air is not drawn in evenly into the engine, but with a rhythmical motion, as in the human body, air being breathed in during each up-stroke of the piston of a two-stroke engine, and during every alternate down-stroke of a four-stroke engine. It is similarly discharged at intervals, the intervals of taking in and discharging of air occurring alternately as in the human body. In the human body inspiration and expiration of air are caused mainly by expansion and contraction of the diaphragm and ribs, the chest being alternately expanded and contracted and the diaphragm also at the same time being contracted and expanded, so that the chest cavity

acts as a kind of bellows in drawing in and discharging the air. In the engine, inspiration and expiration are effected somewhat similarly. Air is drawn in through the carburettor as a result of the expansion of the cylinder head cavity and expelled through the exhaust pipe as a result of the contraction of the cavity. The cylinder head cavity of a four-stroke engine thus acts somewhat as a bellows in drawing in and expelling air. Some types of carburettors have a contrivance, consisting of a plate which rises and falls with the pulsations of the engine. This contrivance is called the diaphragm; and the name shows it is a mechanical copy of the diaphragm of the body of a creature. The springs and other devices which control the actions of the mechanical diaphragm correspond to the springs and other devices formed by the muscles which control the actions of the diaphragm of a creature.

The alimentary canal, or food canal, of the human body is fairly well reproduced by parts of the engine. Many of the parts of the canal are co-terminous with many of the parts of the respiratory canal, as in the human body.

The intake pipe or inlet manifold reproduces features of the gullet, or oesophagus, for it allows the passage of the food which is consumed or burnt in the engine; and forms part of the alimentary canal of the engine. The stomach is formed partly by the petrol tank, partly by the oil tank if a separate oil tank is provided, and partly by the sump. The positions of the various parts of the alimentary canal, or intestines, vary in different types of the engine.

The alimentary canal begins where the petrol and oil are put in; and the engine usually has two or three mouths, or extensions of the mouth of the alimentary canal. Tracing the path taken by the petrol, we can see that a mouth of the canal is formed by the mouth or opening of the petrol tank.* From the petrol tank a tube leads into the float chamber of

* "The fuel is poured through a mouth or opening into a stomach or tank; from the tank the petrol is carried by means of a feed-pipe — the alimentary canal—to an apparatus — the carburettor — which absorbs the petrol and transforms it into a combustion mixture." Sir Arthur Keith, M.D., LL.D., D.Sc., F.R.S., *The Engines of the Human Body.*

the carburettor, which is really an enlargement of the tube. †
The tube becomes constricted where the device of the float chamber regulates the amount of petrol issuing from the stomach, or petrol tank. This device consists of a needle point held in a small hole by the float. As the float falls, the needle's point comes away from the hole and more petrol flows from the stomach to the next part of the intestine, this next part being the float chamber. The device which regulates the amount of petrol allowed to pass from the petrol tank into the float chamber corresponds to and reproduces actions of the pylorus of a creature which regulates the amount of food which is allowed to pass from the stomach to the duodenum, or next part of the alimentary canal. Food does not pass continuously from the human stomach to the duodenum. When a small quantity, say half an ounce, has passed, the pyloric muscle closes. After an interval, another small quantity is allowed to pass. The valve formed by the needle and hole acts very similarly to the pyloric sphincter or muscle, and allows only small quantities of petrol to pass at intervals from the stomach of the engine into the float chamber; and the float chamber itself therefore probably corresponds to the duodenum. ‡

After entering the duodenum, or float chamber, of the engine, the petrol enters the small tube formed by the jet. Thereafter it changes its character, as food changes its character as it proceeds along the intestines, and becomes mixed with air. From the jet the petrol now mixed with air, proceeds along a much larger tube, the inlet manifold. The tube or canal enlarges again in the cylinder head, becomes constricted again as the gas now consisting of waste products enters the outlet tube and exhaust pipe. The waste products of combustion are discharged through the aperture of the exhaust pipe, which is usually at the rear end of a motor car

† "The carburettor . . . corresponds to an elaborate machinery which has been built into the containing wall of the alimentary system of the human body . . . ". *Ibid.*

‡ According to Sir Arthur Keith, "At the carburettor the alimentary canal ceases . . . " It seems however that it is continued through the engine and ends at the extremity of the exhaust pipe.

when the engine is fitted to a motor car, the aperture forming an anus.

The alimentary canal of the four-stroke engine is formed mainly by the tubes and cavities through which the petrol and air pass and the waste products of combustion are ejected. But that of the two-stroke engine has an extension formed by the crank-case cavity. The two-stroke engine consumes petrol and oil and air, and is sometimes called a petroil engine. The air breathed in through the carburettor mixes with the oil and petrol spray from the jet, and the mixture in the form of a mist or rarified fluid after going through the intake pipe instead of going immediately into the cylinder head cavity is deflected into the crank-case and is then directed through a duct or pipe formed by a port in the cylinder wall into the cylinder head cavity. The crank-case thus forms part of the alimentary or food canal.

The crank-case cavity also probably forms an extension of the alimentary canal of the four-stroke engine; but the petrol and air do not go through it, and only the oil which lubricates the crank-shaft and its bearings and piston rings is contained in it. There is almost no communication between the crank-case cavity and the rest of the canal; but some of the oil left on the sides of the cylinder as the piston descends mixes with the petrol and air and is consumed in the cylinder head cavity. That some of the oil is consumed becomes evident if the piston rings do not fit well. The rate of oil consumption then rises rapidly and reveals that oil is passing past the piston rings, and that there is a communication between the two parts of the alimentary canal.

The part of the alimentary canal formed by the crank-case is however usually almost separate from the part formed by the tubes through which petrol, air, and waste products pass; and is provided with a separate mouth, this mouth being an extension of the mouth formed by the petrol tank or opening, and being formed by the opening through which oil is poured into the crank-case.

The rectum of the engine is formed by the sump. This requires to be emptied periodically; and waste oil, grit, dirt,

and bits of carbon, are emptied through the hole in the bottom, the hole corresponding to the anus of a creature. A bolt is screwed in to close the anus. A creature's anus is closed by the strong sphincter muscles which surround the aperture. The internal combustion engine therefore has two anuses, one at the end of the exhaust pipe and the other at the bottom of the sump; and certain waste products are discharged through one anus and certain others through the other anus.

The food of the engine is petrol and air, or petrol and oil and air, or oil and air, depending on the type of engine; and it undergoes a process of combustion or consumption in the cavity of the cylinder head; and it is in this part of the alimentary canal that the main processes corresponding to those of digestion occur. According to the theory now advanced by certain eminent authorities petrol is food which is already nearly fully prepared and ready for digestion. Thus Sir Arthur Keith, an eminent authority on the anatomy of the human body, writes:— "The stomach of a motor cycle . . . must be fed with fuel already digested—already in a condition suitable to form the basis of a combustion mixture. Petrol, the food of engines, if modern geologists are rightly informed, is the fuel which was stored up in the livers of extinct animals . . . In the livers of living sharks and certain other fish we know that there is stored up a carbohydrate material, very similar to petrol, which is used by them as fuel to drive their muscular engines in swimming. The petrol which carries a cyclist so swiftly along we are justified in regarding as fuel which extinct monsters had stored up in their livers many millions of years ago to carry them through old-world seas in search of prey."[1] Part of the food of the engine, formed by the oil in the sump, is consumed in the crank-case; and processes of digestion therefore occur also in the crank-case.

The alimentary canal of the engine is of considerable total length and perhaps is as long or even longer sometimes than the alimentary canal of the human body which is about

[1] Sir Arthur Keith, M.D., LL.D., D.Sc., F.R.S., *The Engines of the Human Body*.

twenty eight feet long. In man the canal is twisted or convoluted and is not of constant diameter along its length; and somewhat similarly the canal of the engine is not straight but has many curves and is not of constant diameter along its length. It differs considerably in shape and length and bore from the alimentary canal of a gun, which consists of a nearly straight and cylindrical tube. The shape and length and bore of the alimentary canal varies considerably in different creatures; and the alimentary canal of a gun resembles that of a creature like the common earthworm, whose canal is nearly cylindrical and straight, more than it resembles the canal of the human body.

It is now evident that the alimentary canal as well as the respiratory organs are reproduced by the engine. Some of the parts of the respiratory organs serve also as parts of the alimentary canal; and there is much economy of apparatus. But the two systems are not co-terminous. For example, the mouth of the respiratory organs is formed by the mouth of the carburettor, but the mouth of the alimentary canal by the openings of the petrol and oil tanks. Or again, the part of the alimentary canal formed by the petrol tank and tube leading from it to the carburettor does not form part of the respiratory organs.

It will now be shown that the heart is reproduced by the engine. It will perhaps be easiest to begin the study of the engine's heart with a study of the common pump, for the actions of a pump copy those of the heart of a creature.

The piston of the common pump divides the cylinder or barrel in which it works into two cavities, one above and one below the piston. The cavities are equal in size only when the piston is at the mid-point of its upward or downward stroke. As the piston ascends, the lower cavity increases and the upper one decreases in size; and, conversely, as it descends, the lower cavity decreases and the upper one increases in size. As the handle is pressed down, the piston rises; and the water flows up through the pipe from the well, into the cavity below the piston; and at the same time the water resting on the top of the piston is expelled

from the upper cavity, and out through the spout. Since the water is received into the lower cavity and expelled from the

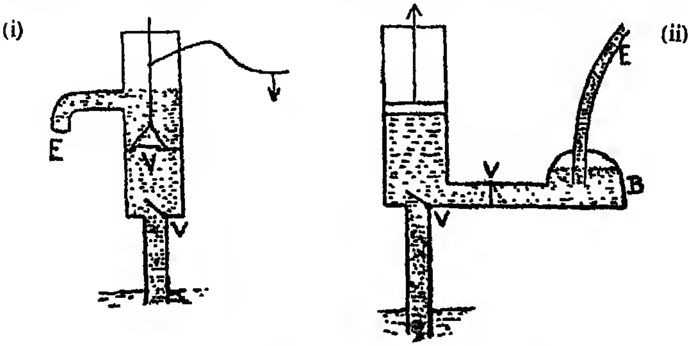


FIG. 72.
(i) Common pump (ii) Force pump
V, valve; E, exit pipe; B, chamber partly filled with air.

upper one, the lower one acts somewhat like an auricle or receiving cavity of the heart, and the upper one like a ventricle or expelling cavity. The passage of the water from the lower to the upper cavity through the flap valve in the piston as the piston descends corresponds to the passage of the blood from an auricle to the ventricle; and the entry of the water from the pipe into the auricle, or lower cavity, corresponds to the entry of blood from a vein into an auricle; and the expulsion of the water from the spout corresponds to the expulsion of blood from a ventricle through an artery. The chambers or cavities of a heart do not remain constant in size, but expand and contract rhythmically; and similarly the chambers or cavities of the pump do not remain constant in size, but expand and contract rhythmically as the handle is worked.

It is evident therefore that the structure and actions of a heart and of the common pump are very similar in many respects. But the author is not the first to point out this fact; and indeed nearly every writer on the biology or anatomy of the body notes the similarities of the actions of a pump and of the heart. It can therefore be taken for granted that the lower cavity acts as an auricle and the upper one as a

ventricle; that the cavities expand and contract rhythmically; and so on.

The common pump has only one auricle and one ventricle. Many creatures have a heart consisting of only one auricle and one ventricle. Fishes and snails and slugs, for example, have this type of heart. The common pump therefore has a type of heart which corresponds to the type of heart of a creature having one auricle and one ventricle.

In the common forcing pump, the cylinder in which the piston works, acts alternately as an auricle and then as a ventricle; and an auricle and a ventricle are not formed at the same time. There is no valve in the piston, which is solid; and as the piston rises, water is pushed up, by atmospheric pressure, from the well into the cavity created by the ascending piston. When the piston begins to descend a flap valve closes the entrance to the pipe leading from the well, and the water cannot return to the well but is forced up another pipe to, say, the top of a building. A valve in this exit pipe prevents the water running back as the piston draws up the next charge of water from the well.

When water enters the cylinder as the piston rises, the cavity formed by the ascending piston becomes an auricle, or receiving vessel; but when the piston descends, the cavity below becomes a ventricle, or vessel from which fluid is expelled.

Water is expelled from the common forcing pump only while the piston is descending; and is therefore expelled with an intermittent and not with a continuous action. The action is sometimes made more continuous by providing an additional chamber or cavity at a point on the exit pipe. The exit pipe is led into this cavity which is partly filled with air. The pipe leading to the top of the building projects downwards into this air tight cavity so that its nozzle or mouth is below the level of the water in the cavity. As the piston descends, it forces the water into the cavity. This compresses the air there, and the compressed air continues to drive the water up the pipe to the top of the building even while the piston is drawing up water from the well. The additional

cavity corresponds to the bulbus arteriosus of a creature. This is a bulb-like extension of the ventricle, acting as a kind of additional ventricle. In the fish, for example, there is a pronounced bulbus arteriosus; and the blood after entering the ventricle from the auricle is sent into the bulbus arteriosus before being forced along the branchial artery to the gills. The bulbus arteriosus is not evident in all fishes. It is evident in the frog; but seems to disappear in man.

The bulbus arteriosus can also be seen, in a mechanical form, in the "manual" fire engine pump, or hand operated double cylinder pump which sends a continuous stream of water through a hose. This type of pump has two auricles and two ventricles, an auricle being formed by each cylinder as its piston ascends and a ventricle as its piston descends. The bulbus arteriosus is reproduced by the air chamber into which water is forced by the two pistons, the water passing through the mechanical bulbus arteriosus before being sent along the branchial artery, represented by the hose pipe.

The mechanical bulbus arteriosus, or additional chamber, of the pump may be regarded either as an extension of the piston chamber or as an expansion of the exit pipe. Similarly, it is possible to regard the bulbus arteriosus of a creature as an extension of the ventricle or as an expansion of the artery leading to the lungs or gills. The additional chamber of the pump helps to make the passage of water through the outlet pipe more continuous, and smooths the actions of the auricle and ventricle, acting somewhat as a shock absorber. By analogy, some of the purposes of the bulbus arteriosus of a creature are to make the passage of the blood through the artery more continuous, and to smooth the actions of the auricle and ventricle and perform the work of a shock absorber. The mechanical bulbus arteriosus is modified in some types of pumps and seems to disappear in others; and no doubt a study of different types of pumps would help to show why the bulbus arteriosus is modified in different creatures and seems to disappear in others.

Four strokes of the piston are required to complete the power stroke of a four-stroke internal combustion engine; and

it can be seen that the cavity above the piston, or cavity of the cylinder head, acts successively like the left auricle, left ventricle, right auricle, and right ventricle of a creature with a heart with four cavities.

The actions of the four-stroke engine the reader will know are, briefly, as follows: — The piston on the first down stroke sucks in gas into the cylinder head cavity, through the inlet valve. On the up-stroke the gas is compressed, and when fully compressed is burnt or consumed, and the expansion of the gas drives the piston down. On the next up-stroke, the piston drives out the spent gas from the cylinder head cavity along the outlet and exhaust pipes into the atmosphere. The gas, as has been indicated and as will be more fully explained later, has certain features and properties corresponding to those of the blood.

Although the heart of the four-stroke engine has only one cavity, namely that above the piston, the cavity in turn serves the purpose, or some of the purposes, of the four cavities of the human heart. The entry of the mixture of petrol and air, which is a type of rarified fluid, into the cylinder head cavity corresponds to the entry of the pure blood into the heart from the lungs. The tube through which the gas is drawn, that is the induction pipe, corresponds to the pulmonary veins through which the pure blood from the lungs is drawn into the heart. The pure blood enters the left auricle of the human heart; and therefore on this occasion the cylinder head cavity corresponds to the left auricle of the human heart. As the piston rises, it compresses the gas; and the cylinder head cavity now acts as a left ventricle, for it is in the left ventricle of the heart that the pure blood is compressed. In the body there is an artery, the aortic artery, to allow the pure blood to escape; but there is no corresponding tube or artery in the four-stroke engine, and the pure gas cannot escape. When the gas is fully compressed, it is consumed or burnt; and the expansion of the consumed gas forces down the piston. At this time, during the downstroke of the piston, the cylinder head cavity corresponds to the right auricle, the cavity then being filled not with pure but

with impure or burnt gas, as the right auricle is filled with impure or venous blood from the body. No separate tubes are provided in the four-stroke engine to represent the venae cavae, or great veins which carry the blood from the body to the heart; and the change from pure to impure gas takes place in the cylinder head cavity, without any exit of the pure and entry of the impure gas. The piston as it rises for the second time pumps out the impure gas into the exhaust pipe. The cylinder head cavity therefore, while the piston is ascending, corresponds to the right ventricle; and the exhaust pipe corresponds to the pulmonary artery through which the impure blood passes to the lungs to be regenerated by the atmosphere. The impure gas is sent straight out into the atmosphere to be regenerated; and the regeneration cycle is not completed within the engine.

Thus, although the heart of the four-stroke engine has only one cavity, formed by the cylinder head cavity, it can be regarded as a four-chambered heart; for the cavity in turn serves as a left auricle, left ventricle, right auricle, and right ventricle. It is filled with pure gas from the lungs of the engine, formed by mechanisms between the carburettor's mouth and the inlet valve, and the pure gas enters the cylinder head cavity through the pulmonary veins of the engine, formed by the intake or induction pipe, the veins being represented by the single intake or induction pipe. The impure gas is discharged through the pulmonary artery, represented by the exhaust pipe. The venae cavae and the aorta are not represented; but possibly the intake and outlet tubes besides representing the pulmonary tubes represent also the venae cavae and aortic tubes.

The heart of the four-stroke engine can however be regarded as a single chambered heart, a type of heart found in many creatures; and the rarified fluid, or gas, as being drawn in through one tube and expelled through another, the heart being formed merely by a tube which enlarges at the cylinder head.

Or, the mechanical heart can be regarded as a double chambered heart, and as consisting merely of an auricle and

a ventricle, the rarified fluid being drawn in through one tube into the auricle formed by the cylinder head cavity, and discharged from the ventricle formed by the same cavity.

The heart is modified in the two-stroke engine. The rarified fluid, formed by a mixture of petrol, oil, and air, is not drawn from the carburettor directly into the cylinder head cavity, but is drawn into the crank-case cavity. The heart is perhaps a three chambered type, or one having two auricles and a single ventricle, a type of heart possessed by creatures like snakes, tortoises, and frogs. The ways the cavities act is not clear to the author, but possibly is as follows:— The crank-case serves as a left auricle for it receives the pure or unburnt gas from the pulmonary veins of the engine, in much the same way as the left auricle receives the pure blood from the pulmonary veins of the creature. The cylinder head cavity when ready for combustion to begin is filled with pure gas slightly mixed with impure or burnt gas, and perhaps corresponds then to the ventricle which is filled with pure blood mixed or slightly mixed with impure blood. The cylinder head cavity after the explosion or combustion of the gases contains impure or burnt gases and then corresponds to and acts as the right auricle which is the vessel or chamber that receives the impure blood from the body of the creature. But the author is not sure he has correctly seen the actions of the heart of the two-stroke engine. Probably his readers will quickly see the correct solutions of its actions.

The valves of the common pump are simple hinged valves or flaps without stems or springs, which allow the water to flow only in one direction; and they are operated merely by the movement of the water, opening when the water flows in one direction and closing when it tries to flow in the other direction. They reproduce some of the features and actions of the hinged valves of the heart, the aortic and the pulmonary valves, which allow the blood to flow only in one direction from the heart to the aortic artery and pulmonary artery. The valves of a four-stroke engine are not hinged valves, but are provided with stems and springs, and reproduce features and actions of the mitral and tricuspid valves

of the human heart which allow the blood to flow from the auricles to the ventricles. The head of the four-stroke engine's valve corresponds to the cusp or flap of the human valve; and the stem reproduces features of the chordae tendinae, or cords which join the valve heads to bases formed by the papillary muscles. The mechanical valve springs reproduce actions of the papillary muscles of the cusps which regulate the movements of the valve cords and cusps, or valve stems and heads.

The cavities or chambers of the human heart contract and expand with rhythmical movements. Similarly, the cavities of the heart of the engine contract and expand rhythmically. The contraction of the upper cavity, or cavity of the cylinder head, is greatest when the piston is at the top of its stroke, and the expansion greatest when it is at the bottom of its stroke. The crank-case cavity, conversely, is contracted most in area of its walls and volume when the piston is at the bottom and expanded most when it is at the top of its stroke. Hence, although the cylinder and crankcase walls are made of inflexible materials, contraction and expansion of the walls occurs regularly, much as in the heart of a creature.

The two main compartments of the human heart, each consisting of an auricle and its corresponding ventricle, are not in direct communication with each other; and so the pure blood and the impure blood do not mix. In many creatures, reptiles for example, the pure and impure blood streams are not kept separate but mix, either in the heart or near it. The two blood circulatory systems of the four-stroke engine, represented by the pure gas circulatory system and the impure gas circulatory system, are not in communication with each other, and the pure and impure gases are not mixed. It is true, pure gas at one time and impure gas at a subsequent time are found in the same cylinder head cavity; but the gases are not mixed, and the pure gas, as has been explained, is found only in the left auricle and left ventricle, and the impure gas only in the right auricle and right ventricle. The blood circulatory system of the four-stroke engine therefore resembles that in creatures in which the pure

and impure blood streams are not mixed. In the two-stroke engine the separation of the pure and impure gases is not so effective, and the pure and impure gases do mix to some extent. This is because of the difficulties of arranging the ducts or ports of the cylinder walls satisfactorily enough to prevent the pure and impure gases mixing; and usually some of the pure gas and some of the impure gas becomes mixed in the cylinder head cavity, resulting in a loss of efficiency. Thus there is direct communication at times between the two gas circulatory systems of the two-stroke engine, as there is direct communication between the two blood circulatory systems of some creatures; and the pure gas and impure gas become mixed in the engine as the pure blood and impure blood become mixed in the engine of a creature like a reptile.

Our study of the internal combustion engine has already revealed that the mechanical engine reproduces many features of the engine of a creature. It has been shown that it reproduces features of the nostrils, mouth, throat, and windpipe, that it has lungs, that it has an alimentary canal with features of a stomach and intestines, that it has a heart, and that it has two blood circulatory systems. Besides possessing these organs, it will presently be shown the engine has other organs corresponding to organs of living creatures; and it will also be seen that it has no mechanisms or organs which do not correspond to organs of creatures. Since the internal combustion engine has several organs corresponding to those of creatures, it must therefore be studied as a creature is studied, and must be regarded as a type of creature. It is perhaps not the same type of creature as a living creature, but this is not certain, because evidence will accumulate which will suggest it is developing to become a living creature. But an immense period, perhaps to be reckoned in geological ages, it seems will be required before man can develop any mechanical machine to full correspondence to any machine of the body.

The rate at which the heart of the engine beats can be compared to the rate at which the heart of a creature beats.

Different types of the internal combustion engine work at different rates. The normal rate of working of a gas engine may be as low as 80 revolutions a minute. A motor car's engine may make more than 6,000 revolutions a minute. Since it requires two revolutions of a four-stroke engine to complete the cycle of a heart beat, and one revolution of a two-stroke engine, a two-stroke engine working at say 80 revolutions a minute has a heart beat of 80 a minute, and a four-stroke petrol engine working at say 2,000 revolutions a minute has a heart beat of 1,000 a minute. The rate at which the heart beats varies in different creatures. In man it beats about 70 times a minute, in a frog 20 times, in a horse 30 times, in a mouse 700 times, and in a canary it may beat 1,000 times a minute which is equivalent to a four-stroke engine's 2,000 revolutions a minute. The rate at which the heart of a creature beats can be varied by the actions of its accelerator which is formed by its vagus and sympathetic nerves. Somewhat similarly the rate at which the heart of an engine beats is regulated by actions of the accelerator. The ways in which the engine is controlled will be more fully studied later.

Sounds are produced by the heart beats both in creatures and machines. The sounds made by the beating of the heart of the common pump can be heard as the handle is worked and the water is made to move from the auricle to the ventricle and from the spout. Those made by the heart of the internal combustion engine are heard as the gases are expelled from the cylinder head cavity and exhaust pipe. The heart beats of an engine are louder than those of a creature, a sign of the inefficiency of the mechanical contrivance, for the more efficient a machine the more quietly as a rule it works.

The head of a creature is reproduced by the cylinder head, as correspondence of names shows. There are ventricles in the human head, and probably these are reproduced in turn by the cylinder head cavity. But the features of the head are not easily studied.

After the food in the body of a creature has been digested,

it diffuses or percolates through the linings of the intestines into the blood, and is carried in the blood to all parts of the body. The food products are represented in the internal combustion engine by the diffused petrol and air, or petrol and oil and air, which form a kind of rarified fluid or gas. Hence, the circulation of the gas in the engine has some correspondences to and reproduces some of the features of the circulation of the blood in the body.

The rarified fluid, or gas, formed by petrol and air, is colourless. But the fluid may have a slightly yellow colour when it is formed by petrol and oil and air or oil and air. About 1945 petrol for commercial vehicles was coloured red, and was popularly known as red petrol. The gas stream in engines using red petrol reproduces the red colour of the blood. Little progress, however, has yet been made in developing the petrol or oil fluid to correspond to the blood in colour.

Food products form only some of the constituents of the blood. A considerable proportion of the blood consists of water; and therefore the human body has a water circulatory system, the tubes being formed by the arteries and veins and their capillaries or branches. The system is operated partly by the heart, which receives the water of the blood into the auricles and pumps it out through the ventricles, the water being thus circulated through the different parts of the body.

In the human body the water, as part of the blood, circulates through the various tubes of the arteries and veins and their branches, and passes through the heart. But in the internal combustion engine the water tubes do not pass through the cylinder head cavity, or heart of the engine. The water circulatory system of the mechanical engine can therefore best be compared to the water circulatory systems of those creatures in which the water canals or tubes do not pass through the heart. Star fishes and sea urchins, for example, have a water circulatory system whose tubes do not pass through the heart. The water, in these creatures, is drawn through a perforated plate, the madreporic plate, which somewhat resembles the rose of a watering can. The water

circulatory system of the internal combustion engine reproduces many features of the water circulatory system of such creatures, and seems to be a rudimentary copy of it. The water ducts and tubes of the engine correspond to the water ducts and tubes of the creatures, and the radiator corresponds to the madreporic plate. The madreporic plate communicates at intervals with outside water supplies when the creature is out of the water but continuously when it is in the water. The radiator of a motor car communicates only at intervals with outside water supplies, communication being established only when the radiator is being filled or emptied.

The water circulatory mechanisms of the internal combustion engine have been derived from such contrivances as the water heating mechanisms of buildings and the water jacketed bellows of the blacksmith. The tuyere or bellows' mouth is sometimes surrounded by a water jacket to keep it cool; and the water is fed from a tank placed at a height above the bellows to ensure circulation of water as the mouth of the bellows becomes heated.[2]

The water is not always circulated by mechanisms connected to the heart of the engine, but is often indirectly circulated through heat produced by its actions. The water circulatory system consists of large ducts or tubes surrounding various parts of the cylinder and developing into fine tubes or cells in the radiator. The large ducts correspond to the arterios and veins of the body, and the fine tubes or cells of the radiator correspond to the small tubes or cells into which the arteries and veins develop. The water however is sometimes made to circulate in the engine by means of a pump operated by mechanisms connected to the heart of the engine, and the pump is probably an extension of the pump of the heart of the engine.

The urinary system of the body is reproduced by the engine. The urethra tube for letting out water is mechanized partly as the short duct at the bottom of the radiator, through which water is emptied, and partly by the longer overflow tube sometimes placed behind and proceeding from

[2] *The Badminton Library*, Motors and Motoring.

the top to the bottom of the radiator. One water exit is much longer than the other, and perhaps the longer tube corresponds to the male and the shorter duct to the female urethra of the human body, but the author cannot state this certainly. The male tube is longer and the female duct shorter than in the human body.

To prevent the water freezing in cold weather, certain chemicals are put in the water; but the author does not know if the addition of these chemicals results in the fluid corresponding more closely to urine. When these chemicals become more developed, perhaps correspondences will become marked. The fluid from the radiator like that from the body is emptied only periodically. The author does not know if the bladder and kidneys are reproduced by the engine; but possibly the two ureters, or tubes which lead the urine from the kidneys to the bladder are reproduced by the two tubes which connect the radiator to the rest of the water circulatory system. If the bladder is represented, it is perhaps formed by the cavity at the top of the radiator.

Blood consists of other materials and substances besides food products and water; and therefore the blood circulatory system consists of other systems besides a food product circulatory system and a water circulatory system. One of these other systems is an oil circulatory system, by means of which oil and other lubricating fluids and materials are carried to various parts of the body. The joints of the limbs, for example, are lubricated with a kind of oil called the synovial fluid; and all other moving parts are lubricated with appropriate types of fluids or materials. The oil circulatory system in the body is combined with the food circulatory and water circulatory systems; but is separately mechanized in the internal combustion engine. It is difficult to see the oil circulatory system of the body by a direct study of the body; but in the internal combustion engine the oil circulatory system is often almost separate from the food product and water circulatory systems and other circulatory systems, and can therefore easily be studied, and by analogy much can be learnt about the oil circulatory system of the body.

The oil circulatory system in no type of engine is fully separated from the food product and water circulatory systems. Some of the oil in the sump of a four-stroke engine, for example, escapes past the piston rings and mingles with the petrol vapour in the cylinder head, and is burnt or consumed as part of the engine's food. In the two-stroke engine, the oil circulatory system is co-terminous with much of the food circulatory sytem, and the oil which lubricates the engine is drawn in with the petrol and air. In all types of the engine, some water vapour is drawn in with the air through the carburettor, especially in damp and foggy weather; and the water circulatory system is therefore not quite distinct from the food product circulatory system. But in the four-stroke engine, the oil circulatory system is very nearly separate from the other circulatory systems.

The oil in the sump may be made to circulate round the crank-shaft bearings, pistons, and other moving parts of the interior of the engine merely by being splashed about the inside of the crank-case. The various joints and bearings outside the crank-case, as for example the joints of the accelerator and brake pedals and rods and the gear box wheels, may be lubricated by the crude method of oiling from an oil can. The oil can is not properly connected to the oiling system; and this method of oiling may be compared to one necessary if a person had to oil the joints of his body with an oil can. The oil can is partly combined with the oil circulatory mechanisms in some engines, when tubes or ducts lead from the main oil supply to various bearings and joints; but little progress has yet been made in dispensing with the outside oil can, or rather in including the oil can in the working parts of the oil circulatory system. The oil in some engines is forced through various tubes or ducts in the crank-shaft, main bearings, and other interior parts, by means of a pump which is an extension of the heart pump of the engine. A tube often leads from the circulatory system to the dash board to show the oil pressure. The oil pressure gauge corresponds somewhat to the gauge a doctor uses when he takes the blood pressure of a patient.

The engine has characteristics of a warm blooded and of a cold blooded creature; but is developing to possess more fully the characteristics of a warm blooded creature.

Heat is produced through the combustion of the food, which may be petrol, or petrol and oil, or oil, according to the type of engine. The heat liberated during the process of combustion is communicated to the cylinder walls and piston, and thence to the crank-case, connecting-rod, crank-shaft, inlet and exhaust manifolds, exhaust pipe, and other parts. Heat is carried by the water circulatory system to various parts including the radiator; and the circulation of water tends to maintain a constant temperature throughout the engine, in much the same way as the circulation of the water of the blood helps to maintain a constant temperature throughout the body.

Because heat is continually being generated, some of it must be dissipated to the surrounding atmosphere, so that a constant temperature can be maintained. Heat is lost or dissipated in various ways, which can be seen to correspond to ways heat is lost or dissipated by the body. Much of the heat of the body is lost through radiation from the skin. Much of the heat of the engine is similarly lost from the surfaces of the cylinder, inlet and exhaust manifolds, exhaust pipe, crank-case, radiator, and other surfaces. Much heat is also lost from the body when the exhaust fumes or gases are discharged from the exhaust pipe, formed by the wind-pipe or trachea. Similarly, much heat is lost from the engine when the hot gases are discharged from its exhaust pipe, which it has been explained is an extension of the wind-pipe or trachea of the engine. A small amount of heat is lost from the body on the discharge of the faeces and urine, which occurs periodically and not continuously. In the engine, the faeces are represented by the waste oil drawn from the sump, oil being drawn from the engine while it is hot. The urine is represented by the water, or water and chemicals, drawn from the radiator.

Much heat is lost from the engine as the water passes through the fine tubes or cells of the radiator. The heat lost

in this way probably corresponds to the heat lost from the body from the blood vessels of the skin. In hot weather more blood circulates through these blood vessels than in cold weather, and so more heat is lost when the surrounding atmosphere is hot than when it is colder, thus tending to keep the body at an even temperature. The amount of blood circulating at any time in the blood vessels of the skin is controlled, it is believed, from a thermogenic or thermostatic centre in the brain. Very rudimentary copies of the human temperature controlling mechanisms can be seen in motor cars, the controlling mechanisms being formed by valves in the water circulatory systems, and by radiator shutters, the controlling centres being formed by thermostats.

The thermostat sometimes consists of a strip of metal coiled like the main spring of a watch and inserted in a water tube. As the temperature of the water changes the metal spring expands or contracts and operates a valve. The valve opens as the water heats and closes as it cools, so that the circulation of the water is increased or decreased. When the engine is hot the controlling device therefore allows more water to circulate through the fine tubes or cells of the radiator and thus causes greater loss of heat, and conversely when the engine is colder it restricts the circulation of the water and conserves the heat; and an even temperature of the water and of the engine is thus maintained. The radiator shutter similarly opens as the water heats and closes as it cools, and so either prevents or helps retention of the heat.

While the engine is working, its various parts remain more or less at a constant temperature independently of the temperature of the surrounding atmosphere although, like the human body, the engine is affected by the surrounding temperature. The engine therefore has characteristics of a warm blooded creature. The temperature of cold blooded creatures depends largely upon and corresponds approximately to that of the surrounding medium. When an engine stops working it soon takes the temperature of the surrounding medium, and loses the characteristics of a warm blooded organism. Some creatures have characteristics both of warm

blooded and of cold blooded organisms. Some creatures which hibernate, for example, resemble warm blooded organisms in summer and cold blooded organisms in winter. When an engine is kept in a heated garage, attempts are made to retain in it when it is not working some of the characteristics of a warm blooded creature.

Chapter 59

MOVEMENTS

ENERGY liberated during the combustion of food results in movements of various parts of the body. How energy produces movements of the engine of the body is difficult to discover by direct observation; but by studying the internal combustion engine and mechanical contrivances from which it has been derived, some things about the processes can be discovered.

Two of nature's primary motive forces are moving water and moving air. The ways moving water and moving air produce movements of mechanical contrivances can be seen by studying two toys made by boys, the water wheel and the wind wheel.

The water wheel is supported by two forked sticks stuck in the bed of a stream or rivulet. It usually has four arms projecting from a horizontal spindle placed in the forks of the sticks. The ends of the arms, or paddles, dip into the water, and the momentum of the water drives the paddles round and revolves the wheel. The toy wind wheel is driven by moving air, and is very similar in principle to the toy water wheel. Types of the wind wheel can be seen in gardens on posts, on boys' bicycles, at children's parties, and elsewhere.

The parts played by the water or air can be distinguished from the parts played by the heat generated by the sun. The water wheel is directly driven by the moving water, the wind wheel by moving air. But the water and air are made to move as a result of heat generated by the sun. The wheels are therefore directly driven by moving water or air, but primarily and indirectly by heat generated by the sun. The author need not explain how heat generated by the sun causes movements of air and water; and the reader will be

familiar with the workings of nature's air and water circulatory systems.

The ways movements of mechanical contrivances are caused can therefore be seen. The energy generated by the sun causes momentum to be imparted to water or air which can be imparted to parts of mechanical contrivances to produce movements of mechanical parts. Heat generated by the sun does not directly produce movements, but produces it only by acting on water and air. Movements of parts of the steam engine, the internal combustion engine, and the human engine must therefore, it seems, be caused primarily by the sun generating heat and causing movements of water or air or both which in turn cause movements of parts of the engine.

The energy of the sun need not at once be used to produce movements of air or water. Energy is stored in food, coal, petrol, wood, oil, and many other materials, and can be released at any convenient time. Energy generated by the sun is released in the human body when food is consumed or burnt, in the steam engine when coal or wood or oil is consumed, in the internal combustion engine when petrol or oil is consumed.

Consumption of coal in the furnace of the steam engine converts its energy into heat. This turns the water into gas, or water vapour, and results in the particles of the water vapour or steam being given great velocities or energies. The energies or momenta of the particles are transferred to the piston which then moves and drives other parts. The particles in some types of the steam engine, like the steam turbine engine, move like a jet of water or air; but in the railway engine and all reciprocating engines use is made of a closed cylinder, and this allows the particles of rarified water, or steam, to push against the side of the cylinder cavity opposite the piston, much as a person pushes against a wall to propel himself from it.

The furnace of the steam engine is outside the cylinder, but that of the internal combustion engine is inside the cylinder; and the furnace of the internal combustion engine is

therefore transferred from the outside to the inside of the cylinder (Rule 8). As the petrol is consumed, its energy is released and imparted to the air with which it is mixed, giving the particles of the air great velocities. The energies of the particles are transferred to the piston, and the piston then moves and drives other parts of the engine. It seems therefore that the main use of the fuel whether coal, oil, petrol, or food, is to speed up the motions of mechanical parts; and that the steam engine or internal combustion engine or human engine is driven directly by moving water or air, but indirectly and primarily by the sun.

The method of using moving water or air which has not been artificially heated by food, coal, petrol, wood, or other fuel, is much used today. It is used, for example, to move the wheels of a water wheel or turbine to generate electricity, water being stored in a reservoir and allowed to flow down hill to the water wheel or turbine. It is not thus used for driving the steam engine, because it has been found better to heat the water before allowing it to act on the wheel or turbine or piston, so that the momenta of the water particles can be greatly increased. Also, the heat or energy derived from movements of the sun need not be directly used to move the water, and the water can be moved by energy locked up and stored in coal, wood, petrol, or oil, obtained of course originally from the heat or energy generated by the sun. Also, when using the energy of coal or other fuel, the engine need not remain at the same place, but can itself be driven from place to place by the moving water or air.

The sun generates heat within the earth's atmosphere. It does not of course send heat to the earth. To send heat to the earth would be impossible, if only for the reason that there is a vacuum between the sun and the earth across which no heat can pass.

All theories about heat and light unfortunately have hitherto been based on the untested and unproved assumption that the sun is a hot body, people imagining it to be a kind of blazing bonfire. This naïve and childish idea will have to be discarded with others of a similar sort that have

already been discarded, such as for example the idea that the earth is flat, that the sun revolves round the earth, and so on. If the sun exists, it is a cold or temperate body; and if we could travel through space and land on it, we might find it covered with green fields, rivers, trees, and perhaps there would be snow on the higher mountains and at the poles.

The absurdity of the idea that heat is sent from the sun to the earth is at once apparent. For example, on the assumption that the sun is a bonfire, it is impossible to explain how heat can travel across the vacuum or more than 90,000,000 miles between the sun and the earth. The ordinary household vacuum flask it can be remembered is constructed on the principle that heat does not cross even a few hundredths of an inch of vacuum. The assumption also fails to explain how heat can cross the intense cold of space and then become hot again as it arrives at the earth; how heat can be cold at a few miles above the earth's surface and become warm again as it comes nearer the earth's surface; how heat can come in through the cold window pane, leaving it cold, and then become hot again in the room; how heat can pass through a cold lens and set fire to paper or other flimsy material; how it can pass through a lens made of ice without melting it, and then a few inches away set something on fire; why the sun has not burnt out long ago; why the earth has not become noticeably cooler since early historical times; why there have been ice ages on the earth when according to the bonfire idea the sun must have been much hotter and sending more heat to the earth; it cannot explain what becomes of the enormous quantity of heat sent out from the sun, and why nature should disperse the sun's heat in all directions, of which no more than an infinitesimal fraction can reach the earth; and so on.

The failure to question the truth of the idea that the sun is a blazing bonfire has caused insuperable difficulties in finding satisfactory and simple explanations for the behaviour of light and heat. Even Newton failed to question this popular superstition, and as a result failed to find any satisfactory theory of light and heat; and today, through building on this

superstition, theories of light and heat have become incredibly difficult and complicated. If the foolish and primitive superstition that the sun is a hot body is discarded, as great a simplification may be possible in theories of light and heat as became possible in theories of planetary motions when the superstition that the sun moves round the earth was discarded and replaced by the more correct supposition that the earth itself moves round the sun.

The idea that the sun is a bonfire belongs to barbarism, and is one which people have never thought of testing for its truth. If we discard this barbaric idea, we can begin to solve the problems mentioned above, and theories of heat and light can be greatly simplified.

The reader can himself soon begin to see the answers to the above questions, if he realizes the sun is not a hot body, and that heat and light are generated within the earth's atmosphere, and mainly near its surface. That heat and light are generated mainly near the surface is obvious from the fact that it becomes colder and darker as we ascend, which is another fact that cannot be explained on the theory of the blazing bonfire. According to this theory, it should become lighter and hotter as we ascend, because we then go nearer the sun.

The ways heat and light are generated by the sun passing across the heavens can be fairly well understood from the analogy of the actions of an electroscope. Nearly every laboratory has an electroscope, which consists essentially of an insulated brass cap and rod, with a pair of gold leaves suspended from the lower end of the rod. One of its uses is to show what happens when an electrically charged body is passed over the brass cap. If say, an electrified glass rod is brought near the brass cap without touching it, the leaves diverge, showing some electrical actions are occurring inside the electroscope. This reveals the principles by which the sun heats and lights the earth, the electrified glass rod representing the sun, and the gold leaves materials and substances in the earth's atmosphere and surface capable of being agitated by the sun passing across the heavens in its daily

motion. Heat and light are generated within the earth's atmosphere; and the generation ceases as the sun dips below the horizon, as the excitation of the gold leaves ceases when the glass rod is removed. No heat or light is sent from the sun, any more than any electricity is sent from the glass rod to the brass cap or gold leaves. The sun generates the heat and light, which are probably fundamentally electrical actions and similar to those which occur in the electroscope, within the earth's atmosphere, but the sun neither gives out nor receives heat or light.

We can now begin to know the solutions of the problems mentioned above, or rather the problems do not need solving for they do not arise. The sun's heat does not travel across 90,000,000 miles of vacuum, because the heat for the earth is obtained from the earth, and is generated within the earth's atmosphere by the movement of the sun across the sky. No heat can be received or lost either by the sun or by the earth. Therefore the earth, as a whole, is not cooling, and never was a hot body; and never will "roll onwards lifeless in space", as those who are under the delusion the sun is a blazing bonfire foolishly imagine. The sun cannot burn out, because it is not a burning body; and nature does not dissipate immense quantities of heat uselessly into space. Ice ages and hot ages can alternate on the earth; because as heat is generated in the earth's atmosphere, vegetation takes it in and stores it as a form of energy which can be released later, the energy being stored often in coal and oil deposits. As energy becomes locked up in coal, petrol, and other deposits, less heat can be generated by the sun; and an ice-age begins. If for any reason much of the energy from coal, petrol, and other sources, is set free, more energy becomes available for generation into heat, the climate becomes warmer, and a hot age begins. The growth of vegetation is then accelerated to check this process. After a time a state of equilibrium is reached. The process then begins to be reversed; and so ice and hot ages alternate. Each piece of wood or lump of coal that is burnt, each journey made by a motor car, sets free energy which is turned into heat by the

sun in its daily movements; and the sun thus tries to reverse the process of burning the wood or coal or petrol by making the climate warmer and stimulating the growth of vegetation to store again the energy that has been liberated. If coal and oil and other heat storing agencies release more energy than is taken in by vegetation, a hot age automatically begins. Conversely, if more heat is stored in coal, wood, and other store houses, than is expended, an ice age begins. The greater proportion of the energy available for generation into heat is however stored in other materials than coal and oil and wood and other vegetation. Much energy or heat for example is continually being stored as water is turned into clouds and released as the clouds descend as rain. Probably the energy that could be stored in coal and other vegetation is but a small fraction of the whole free energy; and so the earth can never become ice-bound or too hot for life; and its temperature can vary only within certain limits. Nature's mechanisms for controlling hot ages and ice ages are therefore very simple and easily understood; but are incomprehensible if the sun is assumed to be a bonfire.

A room can be heated by the sun through cold glass because the heat is generated within the room. No heat can pass through cold glass and leave the glass cold and then become hot again. Somewhat similarly, heat does not pass through an ice lens. The attractions or electrical actions of the sun are concentrated by the lens, so that materials can be set on fire.

The action of the sun in exciting heat and causing light impressions within the earth's atmosphere is not instantaneous, but requires about eight minutes to take effect. This can be known because it is said that light "travels" at the rate of 186,000 miles a second approximately. It does not of course travel from the sun to the earth. It can be noticed that although scientists say they know how long light takes to travel from the sun, they never study how long heat takes to travel from the sun, because this problem cannot be investigated on the fiery bonfire assumption.

The reader may protest and say the assumption that the

sun is a bonfire must be correct because photographs have shown flames leaping from the sun, sun spots have been seen on the sun, mathematicians have measured the rate at which light travels from the sun to the earth, scientists think they can account by atomic actions for the sun not having burnt itself out, and so on. But a camera can show the sun moves round the earth. Indeed if a photographic plate is exposed to the sky at night, a star will trace a part of a circle on it; and this will show the star is moving in a circle round the earth, which is obviously wrong. Elaborate measures are taken by astronomers when photographing the stars or planets, so that the earth can move without turning the camera away from the stars or planets. Photographic plates exposed to the sun do not photograph the sun, but photograph some of the effects caused by the sun, and so astronomers see sun spots and other imaginary things. The evidence of the camera cannot be trusted any more than the evidence of the eyes. Pre-Copernican astronomers were able to show the sun moves round the earth from the evidence of their eyes and from common sense, and were able to account almost but not quite satisfactorily for the movements of the planets by immensely complicated theories of eccentrics and epicycles and other devices. But eccentrics and epicycles are now forgotten, and the evidence of our eyes and common sense we know cannot be depended on. It is simpler and easier to think the earth moves round the sun: and it is simpler and easier to believe the sun is a cold body.

Chapter 60

THE NERVOUS SYSTEM

THE engine has a fairly extensive system of nerves which reproduces many features of the human nervous system. We will study an engine fitted to a motor car body, which will somewhat simplify the study of its nervous system.

Some of the nerves of the motor car are formed by the electric wires or cables from the magneto to the sparking plugs and from the battery to the lamps. The nerves formed by electric wires or cables are rudimentary copies of the nerves of the body. A human nerve is an extremely complex organism. It has parts and devices, for example, to allow it to grow, to repair itself, to feed itself, and so on. The mechanical nerve, formed by an electric nerve reproduces only a very few of the features of a human nerve, and reproduces mainly the properties of the human nerve which allow impulses to be transmitted.

There are several types of mechanical nerves, varying from the bare current carrying wire to the complex submarine cable. Unsheathed nerves can be seen in the wires between telegraph posts, sheathed wires in rubber and cotton covered household wires. The mechanical nerve consists sometimes of a copper wire covered with rubber, sometimes of several fine strands of copper wire twisted together along their lengths and sheathed in rubber or cotton or rubber and cotton. The fine copper wires correspond to the fibres of a human nerve. The rubber and cotton sheaths correspond to the sheaths of the human nerve. A human nerve sometimes has two coats or sheaths, an outer coat of connective tissue and a thick inner fatty sheath. The rubber insulation of a mechanical nerve probably corresponds to the inner fatty sheath of the human nerve, and the cotton binding perhaps

corresponds to and reproduces some features of the human sheathing of connective tissue.

A mechanical nerve, like a human nerve, may be single or double. The cable from the magneto to a sparking plug is an example of a single nerve; that from the battery to a lamp, if it has two wires, is an example of a double nerve. One of the wires of a double nerve is an afferent nerve, or one which carries an electric current, the other an efferent nerve, or one which carries back the current. The two nerves of a cable may be merely twisted together, but often are twisted and then covered with additional insulating material, so that the two nerves appear outwardly to be a single nerve. The roots of the nerve are where the cable joins the terminals, the cable dividing into two separate nerves and one nerve going to the positive and the other to the negative terminal. This branching into roots at the terminals copies the branching of a human nerve at its roots, as for example when a sensory nerve and a motor nerve which run together in the human body diverge into two roots, and the sensory nerve joins one terminal and the motor nerve joins another terminal of the spinal column nerve.

The author is not the first to point out correspondences between the structures and materials and methods of working of human nerves and electric cables. Most writers on the biology of the body note similarities between the human and mechanical contrivances.

In a single cylinder engine only one nerve connects the magneto to the cylinder head, joining it at the sparking plug. A two cylinder engine has two nerves from the magneto to the sparking plugs, one nerve going to each sparking plug. In general, the number of nerves from the magneto to the cylinder head corresponds to the number of sparking plugs, provided each cylinder has only one sparking plug; and an eight cylinder engine, for example, usually has eight nerves from the magneto to the heart of the engine. The magneto forms a kind of ganglion, or nerve centre, or plexus of nerves.

The impulse from the magneto is transmitted to the other

end of the nerve at the sparking plug end, in accordance with Rule 8. The impulse allows the combustion or consumption of food, or petrol and air, to begin. It does not cause the combustion, any more than say the top of a hill causes a boulder to roll down the hill after it has been pushed to the top. The boulder rolls down the other side of the hill because of the potential energy it has accumulated as the person pushed it up the hill. The combustion of the food in the cylinder head cavity is caused mainly as a result of the petrol and air having been well mixed and heated and brought to the right conditions for combustion to begin. The impulse, given by the spark, provides the last or final touch, to start combustion. Indeed in many types of the engine, the diesel engine for example, no spark is provided, and the compression and heat of the well prepared air and fuel begins the process of combustion. In the human body, the impulse does not result in an actual spark, and combustion and other processes proceed merely on receipt of impulses, provided conditions are right for the processes to begin.

The nerves which join the battery to the lamps correspond to optic nerves. When the lamp switch on the dash board is moved to the "on" position, the lamps respond and allow the driver to see objects on the road ahead. The wires do not serve merely to give the impulse; they also transmit the energy to produce the light. The lamps then act as mechanical extensions for the eyes of the driver. A lamp does not act as an eye to receive impressions of objects on the road ahead, but excites actions in objects on the road ahead, so that the driver's eyes can receive impressions of them. The lamp's actions compared with those of the driver's eyes are therefore reversed (Rule 11). The mechanical eyes, that is the lamps, are used as mechanical extensions of the driver's eyes only at night time. In the day time he does not need these mechanical extensions; but he uses certain other mechanical extensions both at night time and in the day time.

If he wears spectacles, the lenses of the spectacles form mechanical extensions of the lenses of his eyes. The glass of the windscreen is also a mechanical extension of the

driver's eyes, but not of the lenses of his eyes, as the glass does not magnify or change the directions of the light impressions. The glass corresponds to and is a mechanical extension of the transparent front of the eyes, the cornea, which itself acts as a window for the body. The windscreen glass serves many purposes. One purpose is to receive the dust and dirt and water that otherwise would be received in the driver's eyes. The windscreen glass must therefore, like the human eye, be regularly cleaned. It can be cleaned say by a duster or rag, as the eye can be cleaned by a handkerchief; but this is not a satisfactory method of cleaning the glass. The human eye is cleaned by the eye lid as it passes at intervals over the eye ball. The human wiping device is given a crude mechanical extension by means of the wind screen wiper, which cleans the glass by continually passing over it.

Mechanical wipers are not usually provided for cleaning the glasses of lamps; and the primitive method is used of the driver, or somebody else, scraping or wiping off the dirt and dust and wet with a rag or other material or tool, a method corresponding to washing the grit and dirt and flies from the eye. But mechanical eye lid wipers have been fitted to the lamps of a few motor cars; and perhaps the practice will become general.

The wind screen wiper is sometimes joined to and operated from the manifold pipe or induction pipe, suction causing the movements of the wiper. This arrangement of mechanical devices helps to show the close connection between the eyes and the mouth or nostrils, the mechanical wiper being closely connected to the breathing apparatus of the engine.

The action of switching on the lights of the lamps is a voluntary action, or one performed consciously and deliberately. Most of the voluntary actions of the body are caused by impulses sent to various muscles and other parts by nerves from the main part of the nervous system of the body which lies mostly in the brain and spinal column. The main nervous system of the driver's body is responsible for the action of the hand in switching on the lights, and the nerves

running to the lamps are therefore related to and work in harmony with the nerves of the main part of the human nervous system.

The human body has a secondary nervous system. This is connected to the main nervous system by branch nerves, the rami communicantes; but it is not for the most part under the direct control of the will. This secondary or subsidiary system runs approximately parallel with the first or main system which runs from the brain and through the spinal column, but instead of being enclosed in the spinal column lies more within the body. The main system is the cerebro-spinal system. The second or subsidiary system is called the sympathetic and sometimes the autonomic system. The two names of this second system help us to understand some things about the workings of the internal combustion engine, as we shall see, for although the nerves of the main system of the body of the driver are mostly used for starting the engine, when it has been started the parts of the engine work without his conscious will being exercised, and work mainly under the influences and actions of his sympathetic or autonomic nerves.

The sympathetic nerves of the body are largely responsible for the continuous workings of parts like the breathing tubes, stomach, and heart; and these parts are not operated by the conscious will of a person. But their actions can be influenced to some extent by the will of the person. For example, the heart can be made to beat more quickly by a person becoming excited or taking violent exercise. The rate at which the heart beats, it is believed, is controlled or governed by nerves from the sympathetic system, and also by the vagus nerve, a nerve which originates in the brain and wanders about the body, as its name shows, the word vagus being related to the word vagabond. The sympathetic nerves act as an accelerator on the heart; the vagus nerve acts in the opposite way and decreases the sizes of the breathing tubes and retards the actions of the heart. As nearly every writer on the biology of the body points out, the actions of the sympathetic and vagus nerves correspond to those of the

accelerator pedal of a motor car, for the driver to enlarge the size of the breathing tubes of the engine and to increase the rate at which the heart of the engine beats presses down the pedal, but allows it to ascend to reverse these actions (Rule 11).

The internal combustion engine then, like the human body, has a double system of nerves, some being under the conscious and direct operation of the driver's will, and others acting without his conscious direction. One system corresponds to the main or cerebro-spinal system of nerves of the body; the other to the sympathetic system. An example of a nerve of the engine belonging to and connected to the driver's main system of nerves is the cable to the horn. The horn must be operated each time by the driver, and does not work without his conscious direction to give warning of the motor car's approach. An example of a sympathetic nerve is a cable from the magneto to a sparking plug; for the impulses along the sparking plug nerve are not consciously operated by the driver. By means of the sympathetic nerves, and other sympathetic mechanisms which will soon be described, the engine can indeed continue its actions when the human body is far from it.

Besides sympathetic nerves, the engine has sympathetic mechanisms, which however are largely controlled by the sympathetic nerves. A study of watches and clocks soon makes clear the differences between sympathetic mechanisms and sympathetic nerves. A pocket or wrist watch has no mechanical sympathetic nerves, and the sympathetic nerves are formed only by the body. But it has many sympathetic mechanisms; and these allow it to work and keep time without the conscious operation of the owner. The owner must connect his time mechanisms to those of the watch in order to start the mechanisms; and does this when he winds the watch. Thereafter the watch continues to work under the power given by the owner to the mainspring; and the sympathetic mechanisms formed by the various wheels and other parts continue to work until the power given by the owner is exhausted. The power is not directly provided by the owner

for an electric clock. This has a main nerve connecting it to the nerves of the electrical system of the house; and the clock will continue to work by means of its sympathetic nerve and its sympathetic mechanisms as long as power is transferred to the end of the nerve at the clock end.

Many machines have no autonomic or sympathetic nerves, and their sympathetic mechanisms are not capable of working away from the body. For example, the bicycle has no autonomic nerves, and all its movements depend on nerve actions, voluntary or involuntary, of the cyclist; and when he dismounts the bicycle's actions stop, although reflex actions may allow it to run unsupported for a few yards. The motor cycle has an autonomic system of nerves, formed by the nerves from the magneto to the sparking plug, by nerves from the dynamo to the lamps, and by other nerves or cables; but the balancing movements are not controlled by the bicycle's autonomic nerves, but by the rider's. Since the rider's balancing nerves are not mechanized, the motor bicycle cannot balance itself. The nerves which control balancing movements, it is believed, originate from the part of the brain called the cerebellum which lies under the main brain at the back of the head. They are not given mechanical extensions in the motor bicycle or ordinary bicycle, although the balancing mechanisms are given some mechanical extensions.

A study of the toy water wheel and toy wind wheel reveals that these contrivances have sympathetic mechanisms. In order that the water wheel or wind wheel may continue to work, it must be controlled by the boy. Control is exercised by the boy going to the toy and readjusting it as nature's water or air circulatory system changes. If, for example, the level of the rivulet falls, the boy must lower the forked sticks, or the paddles will not continue to dip into the water. If he neglects to use his control mechanisms, the water wheel may be washed away as the water rises.

The control mechanisms are sometimes given mechanical extensions. Thus, instead of the boy raising or lowering the wheel as the water rises or falls, he may place the wheel on

a floating platform which will rise and fall with the level of the water. The direction of the wind wheel need not be continually changed by the boy as the wind changes its direction, and the wind wheel will change its direction continually according to his wishes if he provides it with a vane or tail, so that the arms always receive the wind.

Ways in which sympathetic mechanisms are constructed and related to the body are well illustrated from the oft told story of Humphrey Potter's mechanization of the valve opening and closing devices of the steam pump. It was his task as a boy in 1713 to form these devices with parts of his body; but he noticed that by connecting certain parts of the engine to others, the engine would open and close its valves at the correct moments. The mechanical parts and actions replaced the human parts and actions, but not entirely, for he was still responsible for opening and closing the valves, but now performed these actions indirectly by means of mechanical extensions.

In the internal combustion engine, control mechanisms are fairly well developed, some of them being formed as has been explained by mechanical nerves formed by electric wires or cables. In the steam engine, control mechanisms are formed by such devices as valve opening and closing mechanisms and safety valves. Like the mechanisms of the stomach and heart and respiratory organs of the body they operate without the conscious will being exercised.

When a motor car is stationary but the engine is running, the nerves or cables from the magneto to the sparking plugs convey the impulses to keep the engine running; and the engine then runs under the control or influence of its sympathetic nerves. If the nerves are disconnected or cut, the heart of the engine ceases to beat, that is the engine stops running. But the heart of a creature can beat or palpitate, if the nerves running to it are cut. The heart of an engine can also continue to beat, under certain conditions, if the nerves or cables are cut; and indeed the hearts of some types of engines beat normally without impulses from external cables.

Many types of the internal combustion engine do not have electrical ignition; and no nerves or cables run to the cylinder head from a magneto to ignite the charge or start its combustion. The diesel engine is a well known example; and the heart of this engine beats without cables or nerves to the cylinder. The charge in the cylinder head, as has been said, burns when compression is sufficient, the heat during compression causing the combustion at the right moment as the fuel is injected into the compressed air. Combustion of the charge occurs in many other varieties of the internal combustion engine without an electrical spark from a cable from a magneto.

It has long been known that the process of combustion will begin if oil vapour mixed with air is brought into contact with a metal surface at a comparatively low temperature. Clerk showed this about 1880 by screwing a bolt into the end of the piston of a two stroke engine, so that the bolt projected well into the combustion chamber. After the engine had run for about fifteen minutes it was found it would run with the ignition switched off, the heated end of the bolt starting the combustion each time the gas was compressed.[1] "Hot bolt" ignition was indeed used for some time afterwards on several types of engines.

A common method of causing combustion to begin is by use of the hot bulb. This is a small bulb extension of the cylinder head cavity, into which gas is forced. Air is drawn into the cylinder cavity, and at an appropriate moment the gas and air are allowed to mix, and combustion then begins.

The bulb forms an extension of the cylinder head cavity, and reproduces features of the bulbus arteriosus of a creature, which serves as an extension of its heart. This bulb extension is pronounced and well formed in the heart of a fish. The fish has a two chambered heart, consisting of one auricle and one ventricle. The bulbus arteriosus is a bulb-like expansion of the artery which takes the blood from the heart to the gills, and is situated where the artery joins the ventricle. Therefore gas engines with hot bulb ignition have

[1] *Encyclopaedia Britannica*, Internal Combustion Engines.

an extension of the heart cavity corresponding to the bulbus arteriosus. The tube leading to the hot bulb, which brings the oil or other fuel, corresponds to the artery joining the heart and the gills or lungs.

The size and form of the bulbus arteriosus vary in different creatures. Somewhat similarly, the form of the mechanical bulb varies in different engines. It is well formed in the "hot bulb" engine, and is almost a separate part, and is seen as a swelling of the tube or artery from the oil chamber. In some types the bulb appears as an expansion of the heart cavity, or cylinder head cavity, but of course still forms part of the artery that leads in the oil. The "hot bulb" is sometimes surrounded by a water jacket, and is then water cooled. The bulb is not apparent in many other types, but is perhaps formed by the cylinder head cavity itself. The hot bulb contrivance, or a part of it, in some engines takes the form of the hot bolt and in others the hot tube. The hot tube consists essentially of a platinum tube a few inches long closed at its outer end and screwed into the combustion chamber so that part of it is inside the cylinder head cavity. It is heated externally by a bunsen burner, and combustion occurs when the mixture of fuel and air reaches the hot inner end of the tube.

From a study of different types of the internal combustion engine, which provide simple and elementary working models of the hearts of creatures, we can thus begin to understand why the heart can beat after removal from the body and even after its outer nerves have been severed.

The impulse from the sparking plug comes just before the power stroke begins. The power stroke begins when the heart cavity has been filled with pure gas and the gas has been fully compressed. This corresponds to the time when the cylinder head cavity acts as a filled left ventricle. It seems therefore probable that the power stroke for the human body is delivered at the moment the blood in the left ventricle is fully compressed, that is at the moment the blood begins to be discharged from the left ventricle through the aorta to various parts of the body. However, the reader may

be better able than the author to compare the actions of the hearts of the body and of the engine, and establish or contradict this theory.

CHAPTER 61

THE PISTON

THE human prototype of the piston, gudgeon pin, and connecting rod, is the contrivance formed by the hand, wrist, and arm, when a person raises water from a well or pool by cupping his hand, as will now be shown.

Water can be raised from a well by the bucket and rope machine, or machine formed when a person draws water from a well with a bucket and rope. Mechanical parts of this machine are formed by the bucket and rope; human parts by the body. The engine which provides the power is not mechanized, and is formed wholly by the body. The mechanical parts are connected to the human parts by the hand and arm, or hands and arms, and are extensions of the human parts. The human parts of the machine cannot easily be directly studied; but some things can be learnt about them indirectly from a study of their mechanical extensions. The bucket is a type of piston. It is not a cylindrical but a conical type, because the upper part is wider than the bottom part, the bucket having the shape of a frustum of a cone, approximately. Compared with the piston of a motor car engine it is upside down, compared with the horizontal piston of a railway engine it is turned through a right angle (Rules 11 & 10). The piston formed by the bucket has a down and up, or reciprocating motion, as it is lowered and raised to draw water. The gudgeon pin is formed by the handle of the bucket. The devices which connect the gudgeon pin to the piston of an engine are represented by the parts of the rope which secure the rope to the handle. These are transferred copies of the gudgeon pin, or wrist pin, devices formed at the upper end of the rope by the hand. The connecting rod is partly artificial and partly human, and is formed by the rope and arm.

The actions of the water on the bucket are reversed, compared with their actions on the piston of a steam engine (Rule 11); because the water vapour pushes or moves the piston of the steam engine, but the bucket piston moves or raises the water.

Water can be raised by using a bucket without a rope, the bucket being held directly by the hand instead of indirectly by the agency of a rope. The cords of the arms are not then given artificial extensions; and the connecting rod is formed solely by the arm. The cylinder to contain the gudgeon pin is not mechanized, and is formed only by the hand and fingers as they enclose the handle, or gudgeon pin. The engine of the machine is not mechanized, and the human engine must directly provide the power to move the piston of the bucket. The person therefore cannot merely by operating levers or pressing buttons lower the bucket and raise it and draw water from the well, as he can do when his engine is sufficiently mechanized by means say of a petrol engine working a pump.

The bucket may be represented by a pot or vase of some kind, and the gudgeon pin is not then mechanized, unless the pot or vase has a handle to be grasped by the hand.

Water can be raised without a pot or other mechanical vessel; and the hand itself may be cupped to form the pot, or piston, to raise the water. Reciprocating movements are performed by the cupped hand and connecting rod formed by the arm, as the hand is lowered and raised. The human prototypes of the piston, gudgeon pin, and connecting rod, can therefore be seen in the human contrivance formed by a hand cupped to raise water from a pool.

Several contrivances of the body are mechanized and externalized in the bucket and windlass machine. In the mechanisms of this machine can be seen prototypes of several of the main parts of the internal combustion engine. The bucket corresponds to the piston, the rope to the connecting rod, the horizontal drum or cylinder on which the rope is wound corresponds to the crank-shaft, and the wheel to the flywheel. The handle of the windlass wheel corresponds to

the starting handle of a motor car. When the starting handle of a motor car is turned, the driver turns the fly wheel and crank-shaft, and moves the piston up and down; and many of the mechanisms and movements of the engine are merely modifications of those of the bucket and windlass contrivance. When the driver turns the starting handle, the piston and crank-shaft and flywheel and many other mechanisms of the engine are immediately connected to and worked by his body, and directly form extensions of his mechanisms. If the engine is accidentally left in gear, all the locomotive and engine mechanisms of the motor car become directly connected to corresponding mechanisms of the driver's body; and the motor car can be made to move forward by turning the starting handle with the engine in gear.

In the common pump machine the water is not raised directly by the human engine. As the handle is worked, a vacuum is created by the piston, and atmospheric pressure then forces the water from the well up through the pipe of the pump. Indirectly of course the human engine raises the water.

The piston has been derived from the cupped hand contrivance; but as we have seen also reproduces certain features of the stomach, heart, and respiratory organs, since it forms part of the walls of the cylinder head cavity of the internal combustion engine. We saw earlier that in much the same way, for example, the knobbed head of a club has been derived from the fist, but reproduces also certain features of the head. Or, as another example, the narrow part of the handle of a lawn tennis racket has been derived from the wrist, but reproduces also features of the throat. These facts we discovered could be explained on the theory that mechanization of the offensive machinery results also in mechanization of the reproductive machinery. It is possible therefore that the cupped hand contrivance is related to, say, the heart in much the same way as the fist is related to the head or the wrist to the throat; and that two machines are mechanized simultaneously when the cupped hand contrivance is mechanized. But the author has not made much

study of the various mechanical contrivances from which the internal combustion engine has been derived, and cannot say if this is so.

The piece of machinery formed by the piston, gudgeon pin, and connecting rod of an engine is similar in many respects to that formed by the wooden cylinder, hand grip, and arm of the pallone player, *Figure 3*. If the ninety three spikes are removed from the bracciale, the resemblances between the two contrivances become very marked. Moreover the movements of a piston and of a bracciale are very similar.

The piston corresponds to the wooden cylinder of the bracciale. The gudgeon pin corresponds to the bar of the bracciale which is grasped by the player's hand. The connecting rod corresponds to the contrivance formed by the arm of the player, the connecting rod of an engine being a mechanical form of the arm or leg.

As the pallone player walks or runs the bracciale and the arm perform piston and connecting rod movements. Indeed piston actions are performed when anyone walks or runs, but are especially pronounced when anyone runs. The forearms are then bent at right angles to the upper arms, and move rhythmically to and fro at the sides of the body, one forearm and fist or hand going forward as the other comes back. As speed is increased or decreased, so are the piston actions accelerated or decreased. The arms move in time with the legs, the right arm and left leg going forward and backward together, and the left arm and right leg keeping time together, the legs like the arms performing connecting rod movements. Small boys are fond of demonstrating the actions of the pistons and connecting rods of railway engines, by shuffling along, with their forearms bent and working backwards and forwards. As they shuffle along they also make chuff-chuff noises, the chuff-chuff noises made by the the railway engine reproducing very poorly the respiratory noises made by small boys.

The bracciale devoid of its spikes is a type of mechanical sleeve, and related to the sleeve of a coat. The sleeve of a

bracciale is found in a modified form inside an internal combustion engine, as part of the sleeve valve mechanism, both sleeve and piston being types of the bracciale. The phrase "sleeve valve" shows that the sleeve valve is related to the sleeve of a coat.

The delivery of the power by a pallone player is demonstrated with clearness and much pomp and ceremony at the beginning of the game. Pallone is closely related to tennis. The scoring, for example, is the same, and the playing area is similarly divided into two courts, the players being separated by a net or some other dividing line. The server in lawn tennis must keep one foot on the ground and may not move forward while serving. In pallone the server, who is called the battitore, is allowed to run, and is provided with an inclined plane down which he runs on to the court to obtain greater momentum. He is provided with an assistant, the mandarino, who holds the ball and lobs it to him as he runs. The ball is hit by the running battitore to the other side of the arena. The way the ball is served is thus described by Dr. A. L. Fisher:—

"When the game is about to commence, one or the other of the inclined planes, according to the fancy of the player who begins the game, is drawn half way out of the recess on to the playing floor, when the man who begins the game, called "battitore", takes his stand upon the top of the trapolino (inclined plane), and extending the hand in which he holds the bracciale towards the opposite players, he swings it violently backwards and forwards in a semicircle; he then suddenly runs down the trapolino and along the floor towards the middle with all the speed he can command, so as to acquire as much impetus as possible and to strike the ball with more effect. At the time the battitore takes his stand on the trapolino, another man, called "mandarino", places himself on the floor at twenty-five yards in advance of the battitore, and stretching towards him his right hand with the ball in it, he manages to pitch it to him in his forward course, so that it meets him when he is midway between himself and the trapolino. At this moment the ball is about two feet from

the ground. The battitore has the option of striking it or not, according as it comes favourably or the contrary. Should he reject it he resumes his stand upon the trapolino, and the operation is repeated perhaps two or three times . . . If the battitore is of first rate force he will frequently send the ball high over the heads of the opposite party, so that it strikes against the net in front of the gallery or amongst the spectators of that end, causing an immense amount of fun at the expense of the party who may be struck by it: but this is a rare occurrence, for from habit they judge so well of the flight of the ball as to escape by moving a trifle to one side or the other, the amount of mischief in most cases being confined to the smashing of a chair vacated the moment before by the occupant . . . "

By swinging the bracciale violently backwards and forwards in a semi-circle before he begins to run the server winds up his power. As his winding apparatus is not mechanized it is difficult and perhaps not possible to discover much about it by direct observation of his actions; but the mechanical principles of his mechanisms are demonstrated when the spring of a toy engine or of a clock or watch is wound. When the power has been fully wound, the battitore proceeds to use it to propel the ball. Without stopping, which would allow the wound up power to run down, he runs at full speed to the ball and the power is delivered from the piston and transmitted to the ball. The power from the piston of the internal combustion engine is delivered on the downstroke: that from the pallone piston on the up-stroke, the action of the bracciale being reversed compared with that of the piston of an engine (Rule 11). The power from the pallone piston moreover is delivered at right angles to the axis of the arm, that from the piston of an engine along the axis of the connecting rod, the directions of the delivery by the two contrivances thus being at right angles (Rule 10).

The power from the piston of a motor car is transmitted to the crank-shaft, then along the power shaft to the gear box. The spikes of the bracciale are not represented on the piston of an engine; but are probably represented by the cogs or

teeth of the gear wheels. This is suggested by the appearance of a modern bracciale, which has many resemblances to the internal mechanisms of a gear box, the circumferential rows of spikes forming types of gear wheel cogs; and by the fact that spikes like cogs are types of mechanical fingers.

The connecting rod of a piston is a mechanical extension of the connecting rod contrivance formed by the arm or leg when a person runs. When a person walks or runs, the connecting rod formed by a leg pushes the foot against the ground and the person is therefore able to move forwards. When astride a hobby horse, the rider similarly pushes with the connecting rod of his leg; but when astride a modern bicycle he is provided with several mechanical extensions for the connecting rod of his leg, formed by the crank of the pedal, the top part of the chain, the spokes, and other parts, and pushes indirectly on the ground by means of the mechanical extension of the sole of his shoe formed by the part of the tyre in contact with the ground. A child in a toy motor car may push with his feet directly on the ground; but if the machine is provided with pedals, he does not directly tread on the ground, and pushes indirectly on the ground through the agency of the pedals, cranks, chains, spokes, and parts of the tyres in contact with the ground. The driver of a motor car does not push himself along by placing his feet directly on the ground. His legs and feet and the engine of his body are provided with mechanical extensions; and his feet remain almost motionless as the motor car moves. His legs however cannot remain quite motionless, but must still perform some rudimentary running motions. These occur as he moves his feet forwards and backwards, at intervals, to work the brakes, clutch, and accelerator pedals. It is evident therefore that his locomotive and engine mechanisms have not yet been mechanized and externalized sufficiently to allow him to keep his feet still. His hands and arms perform rudimentary piston and connecting rod movements as he steers the motor car. His running or walking movements are also badly distorted, because of

the imperfect development of the mechanisms of the motor car.

The piston therefore pushes on the ground, not directly but indirectly by means of extensions like the connecting rod crank-shaft, propellor shaft, gear wheels, back axle, spokes, and felloes, the felloes finally giving the impulses from the piston to the ground. As has been explained, a felloe of a wheel, or part of the wheel in contact with the ground, is a mechanical extension of the foot. Therefore the piston pushes on the ground by means of a mechanical extension of the foot. But the piston, it has been shown, is also a mechanical extension of the cupped hand. The interior surface of the cupped hand is formed by the palm and insides of the fingers; and when a person walks on his hands and feet, it is the palm and the insides of the fingers or the flat of the foot and insides of the toes that press on the ground and give the impulses to drive him forward.

CHAPTER 62

THE BRAKE

IN order to bring the parts and devices of his body concerned with progression into their correct positions with reference to their mechanical counterparts, the motorist must sit in the driver's seat. If, for example, he sits in the back seat, his mechanisms will not be able to relate and fit themselves conveniently to the parts and devices of the engine and locomotive mechanisms, as he will soon discover. Various parts and devices of the motor car have been given extensions, so that they can conveniently be connected and correlated to his mechanisms when he sits in the driver's seat. Devices of the throat of the carburettor, for example, are given extensions by means of the throttle and choke wires running to the dashboard, and the driver can conveniently enlarge or restrict the breathing tubes of the engine while sitting in the driver's seat. His eyes are given extensions by means of the head lamps, and he can operate them by means of wires from the dashboard. And so on.

The driver brakes himself and the mechanical extensions of his body by putting his foot on the ground and pressing the sole of his foot against the direction of motion. He does not do this directly, but indirectly, his leg and foot and sole being given mechanical extensions by means of the brake mechanisms.

We will now try and see how a driver stops a vehicle when he applies the brake. The brake of a horse drawn vehicle is worked by the driver grasping the handle of a long lever and pulling it towards him. The action of the hand is reversed at the lower end of the lever (Rule 11), as a result of the lever being hinged or provided with a fulcrum; and the lower end of the lever is therefore pushed forward. This action is then transmitted to the end of a rod or cable fastened to the lower end of the lever (Rule 7); and is

transferred to the end of the rod or cable (Rule 8). It is then transferred to the end of another and shorter lever to which the rod or cable is jointed (Rule 7). This lower end of the shorter lever moves forward, and reproduces the action of the lower end of the brake lever, and the action of the driver's hand is reproduced but reversed. The action of the driver's hand is again reversed at the upper end of the shorter lever; and is transferred to a brake shoe or slipper and applied to the rim of the wheel (Rule 7). This action causes friction between the brake shoe or slipper and wheel at right angles to the spokes (Rule 10). This frictional action is transmitted along one of the spokes to the hub (Rule 8), from the hub to the lowest spoke, and from the spoke to the felloe, and this causes the frictional action to be reproduced on the ground. In effect therefore the driver when pulling the brake lever scrapes his hand on the ground, and brings the vehicle to rest. As he does not directly scrape his hand on the ground but does so only indirectly by means of mechanical extensions of his hand, his hand suffers no injury.

Sometimes a person brakes himself by scraping his hands on the ground, as for example when he sits on a grassy slope and slides down it. But it is not the usual practice to use the hands, or fore limbs, and normally the brake is formed by the feet, or hind limbs. If a person running down a hill wants to slow himself down, he applies the brake by pushing the sole of his forward foot down the hill so that friction acts up the hill and checks his motion. If the slope is steep and slippery, he may keep his feet stationary, and use the soles of his feet or shoes as brake skids as he goes down the hill.

Drag shoes or slippers are often used to convert waggons and other vehicles temporarily into sledges as they go down hills. The drag shoe or slipper is a metal plate with sides, somewhat resembling a slipper, on to which the wheel is rolled. When the wheel is on it, a chain keeps the device under the wheel, and the wheel becomes locked. The spokes, or mechanical legs, do not then revolve but remain stationary, much as the legs of a person remain stationary as he

slides or skids down a hill. The wheel instead of being placed on a slipper may be locked merely with a chain or hook, and then skids on the part of the rim or felloe in contact with the ground. This however wears the rim, and the use of a drag shoe or slipper, which can be replaced when worn, is preferable. The drag shoe or slipper corresponds to the shoe of a person or animal; and the contrivance of the spoke on a drag shoe or slipper, or on a locked felloe, corresponds to the contrivance formed by a locked leg, or leg held stiff without being moved, when a creature skids or slides on a surface to brake himself.

A type of brake fitted, until recently, to a bicycle consisted of a rubber shoe which scraped on the top of the front wheel tyre. This brake was applied by means of a lever on the handle bar. Boy cyclists were fond of stopping themselves by means of a similar contrivance which they formed by putting the sole of one of their shoes on top of the tyre of the front wheel. The mechanical and human contrivances were similar in principle and actions; and the prototype of the mechanical contrivance was that formed by the leg and shoe, and its human prototype that formed by the leg and sole of the foot.

Nowadays some of the brakes of the motor car are connected to the sole of the driver's foot, although a hand brake is also used. The sole of the driver's foot is given mechanical extensions by means of the sole of the brake pedal and shoes of the brakes, the shoe of a brake as its name discloses being a mechanical extension of the shoe of the driver. The driver's leg is given mechanical extensions by means of the various levers and rods which transmit and transfer the braking actions of his foot and leg to the shoes of the brake drums and then to the ground. The driver therefore by pressing with the sole of his shoe on the brake pedal really presses on the insides of the brake drums with his shoe, his shoe being given mechanical extensions to allow him to do this conveniently.

It is interesting to notice that the cyclist still stops himself with his hands and not with his feet, for the front and back

wheel brakes are operated by hand levers. Some bicycles however have a back-pedalling brake operated by the foot pressing on the pedal.

A study of the brake mechanisms helps to show the ways in which many other of the mechanisms of the motor car, like the accelerator and clutch mechanisms, are correlated and connected to corresponding mechanisms of the body; and the reader will have little difficulty in working out the details of these other mechanisms and their actions.

Some of the muscles of the driver's body are given mechanical extensions by means of the springs of the gear levers, brake levers, and other parts. For example, the muscles of the leg are given mechanical extensions by means of the strong springs which push up the brake pedal against the foot; and the driver can feel the springs working with the muscles of his leg as he works the brake pedal. Similarly he can feel the muscles of the accelerator pedal or clutch work with those of his leg, the actions of the mechanical muscles being similar to those of the leg, the mechanical muscles tightening or slackening as the muscles of the leg tighten or slacken. The author has not studied in detail the ways in which the muscles of the leg work with the artificial muscles formed by the springs; and there is evidently an important field of research, whose exploration will probably not be difficult, open to any reader who will undertake this study.

The driver sits with his face to the front. The passengers in the ordinary motor car do the same. But sometimes in motor vehicles passengers' seats are placed facing away from the direction of motion or at right angles to it. It can be noticed that passengers always sit either facing or opposite to the direction of motion or at right angles to it. This is true whether the conveyance is a motor car, railway carriage, bicycle, rickshaw, jaunting car, sedan chair, or any other type of conveyance. It seems that passengers' seats can be turned only through a right angle to the direction of motion, or through two right angles (Rules 10 & 11); and that carriage seats cannot be placed obliquely to the direction of

motion. The Rule that contrivances can only be turned through a right angle or be reversed could not be proved incorrect by making a vehicle with seats obliquely to the direction of motion. Such a vehicle could easily be made; but it would be an invention, and therefore would not be widely used, and would soon fall into disuse.

CHAPTER 63

THE HORSE

FOR centuries, perhaps for thousands of years, man has made use of the power machinery of the horse, using it as an extension of his own power machinery. It is a remarkable fact that the power machinery of the horse can be correlated to that of man, so that it can act as a mechanical extension of it. In order that this can be done, certain conditions must be fulfilled. The man, for example, must sit in the correct position on the horse's back and manipulate his own mechanisms in time with those of the horse, as when he rises in the stirrups as the horse trots; or if he wishes the horse to pull him along, must provide some mechanical extensions like wheels, shafts and traces, and correctly relate himself to these mechanical devices.

When connected correctly together, the engine and locomotive contrivances of the horse and of man form a single machine. This was clearly seen by the Peruvians when the Spaniards first arrived in their country. Seeing a horseman for the first time, they were mentally prepared to receive this idea; but the Spaniards through their familiarity with the sight of a horse and man at one time forming a single machine and at other times forming two separate and complete machines were unable to understand that the mechanisms of a horse and its rider form a single machine. On one occasion, during a battle against the Spaniards, the Peruvians were paralyzed through seeing the single machine divide into two machines. "An accident happened to one of the cavaliers. This was a fall from his horse, which so astonished the barbarians, who were not prepared for this division of what seemed one and the same being into two, that, filled with consternation, they fell back, and left a way open for the Christians to regain their vessels."[1] No doubt if a scientist

[1] W. H. Prescott, *History of the Conquest of Peru*, ch. III.

had never seen a horseman, and saw the sudden separation of the machine, as the rider dismounted, into two separate and complete machines, he would proceed to try and study the phenomenon. As he has been brought up to see it happen, he never thinks the phenomenon is worth studying.

It did cause considerable astonishment to civilized people however when it was discovered that the power machinery of the horse could be replaced by a mechanical machine; and until people saw it done they refused to believe it possible. But the internal combustion engine or steam engine is a very crude copy of the engine of a horse's body; and a mechanical engine can serve only some of the purposes of a horse's engine, but can serve a few of its purposes to greater advantage. The mechanical copy can be distorted in size so that the human engine can have a much more powerful extension. When using the horse's engine, all its other machines necessarily must be present; and these other machines are of no direct use to the rider or driver, although perhaps the optical machinery of the horse provides the rider or driver with useful extensions of his own and saves him the trouble of continually guiding the combined machine. When a mechanical engine is used, only one machine is used; and the auditory, scent, growth, self repair, reproductive, and other machines which a horse possesses need not be carried along also. The problems of combining the mechanical engine with locomotive mechanisms, were already partly solved; because the horse's legs and other locomotive parts had been partly mechanized and given extensions by means of wheels, shafts, traces, and other parts of the carriage and harness; and it merely remained to adapt the mechanical extensions to fit the mechanical engine. At first this gave some trouble; and the first motor cars and railway coaches were little different from horse carriages, and often were carriages that had been drawn by horses. At first passengers in trains rode in ordinary horse carriages placed on trucks. Even today the motor car body and railway carriage resemble horse drawn carriages in many respects, notably in such things as door handles, window frames, window straps, positions and

shapes of seats, springs, and wheels. The reader can be reminded that there is never any break in development of anything; and the motor car body and railway coach have been developed only gradually from horse drawn vehicles. There was no break in development when the mechanical engine replaced the horse's engine; and the displacement of the horse was a gradual business and proceeded almost imperceptibly.

The process of replacing the horse's engine by the mechanical engine began with the first making of the engine's parts. The man who first raised water from a well with a bucket or other contrivance made the first piston, gudgeon pin, and connecting rod. The man who first heated water in a pot made the first mechanical water circulatory device; and when he boiled the water or threw fat into the fire made the first water vapour or gas vapour contrivance. The man who fanned the embers of a fire with his breath was the originator of all forced draught contrivances for furnaces. The man who first fanned himself with a leaf was the originator of all modern air cooling and artificial respiratory devices. The man who first spilt grease or fat on the ground and slipped on it, was the originator of all modern oiling systems. And so on. For long the elementary mechanical contrivances were separate. As they were developed into the pump, kettle, bellows, and oil can, the parts of the steam engine and internal combustion engine became more ready for assembly and integration.

It is possible that most of the parts of the internal combustion engine, in undeveloped forms, were in use before man used the engine of the horse. The use of the horse's engine may have been merely a temporary expedient, useful while the parts of the mechanical engine were developing.

It might be thought that the mechanical engine in some ways is better than or superior to the engine of a creature, because for example a motor car or an aeroplane can travel faster than any creature. But nature is not interested in speed as an end in itself. No doubt she could have given her creatures great speeds, if her plans had required it. But

there would be no object say in giving a caterpillar or a mouse speeds of hundreds or thousands of miles an hour; and all creatures have been given powers of locomotion exactly suited to their habits of life. When mechanical machines have been developed as much as possible for speed, ways of developing new powers of the machines will be discovered, and will cause speed to become of less importance, and probably the speeds of mechanical vehicles of the future will correspond more closely to the speeds of creatures.

Chapter 64

THE FRAME OF THE MOTOR CAR

FEATURES of the frame of a vertebrate animal, or animal with a backbone, are reproduced both by the horse carriage and the motor car chassis. The mechanical frame reproduces particularly the frame of the horse; but also reproduces features of the frame of the human body.

Features of the frame of a horse are reproduced differently by different types of horse drawn vehicles. As has been explained, the poles of a travois or Irish slide car reproduce especially the hind legs of the horse. But the two poles, since they bear the weight of the load that would otherwise be borne on the back of the horse, also correspond to and reproduce the backbone of the horse. The two girders, or runners, of a horse drawn sledge, similarly reproduce simultaneously the legs and the backbone of the horse. The cross bars or floor boards reproduce the ribs of the horse, in very crude mechanical forms of course.

But the backbone runs down the middle of the frame of an animal; and therefore two side girders or runners or poles cannot satisfactorily reproduce the backbone. On some horse carriages the girders are dispensed with, and instead a single long pole or rod down the middle connects the front and back axles, and represents the backbone. This pole is called the perch, and, according to coachbuilders, "acts as the backbone of a carriage."[1]

The backbone or perch of the horse carriage is represented in the motor car mainly by the power shaft from the clutch to the gear box, the propellor shaft, and the crank-shaft; and this backbone reproduces certain features of the vertebrae by means of the cogs of the gear wheels, the processes of the mechanical backbone being crowded together at the gear box. But the two runners or poles found on a travois or

[1] John Philipson, M.Inst.M.E., *Coachbuilding*.

sledge are also found in the frame of a motor car as the side girders; and in the process of replacing the engine of the horse with the mechanical engine, the frame of the motor car has reverted to possess features of primitive contrivances like the travois and sledge.

The front axle of the motor car with the track rod reproduces the shoulder girdle, or pectoral girdle, of the horse; and the front wheels reproduce the wheels of the horse's front legs. The back axle reproduces the pelvic girdle; and the back wheels reproduce the wheels of the horse's back legs. These facts can be known, because of the positions of the axles and wheels. The author, however, has not made a sufficient study of vehicles to know to which bones the various parts of the axles, steering rods, etc., correspond; and the solution of these problems must be left to his readers. But it is certain that each part of the frame of a vehicle corresponds to and reproduces, although perhaps in a very crude and rudimentary way, some part or device of the frame of an animal; and that the frame itself is a mechanical embryo of the frame of an animal.

The front axle of a motor car is fixed to the frame; but usually the front axle of a four wheeled carriage is not rigidly fixed to the frame of the carriage, but is hinged and turns with the shafts. Certain devices which allow turning movements of a carriage are, it seems, transferred in the motor car to the back axle. For example, the differential gear in a horse vehicle is on its front axle, but in a motor car on its back axle; and in the motor car "the differential gear acts on the principle of the action of the pair-horse whippletree and equalising bar, the gear acting continuously in a rotating circle while the whippletrees act only through a small range rectilinearly." [2]

The frame of the motor car besides reproducing features of the frame of a horse, also reproduces features of the frame of the driver. Mechanisms of the driver's frame are given extensions by such contrivances as the steering column and rods. This must be so, or the driver could not steer the

[2] *The Badminton Library,* Motors and Motor Driving.

motor car. The body of the vehicle also reproduces features of the bodies of the horse and of the driver and passengers. The seats, for example, since they fit the driver and passengers, obviously are extensions of human parts. The vehicle therefore it seems is a sort of compromise, and has to form simultaneously mechanical extensions of the frames and bodies of the horse and of the driver and passengers.

To discover the human prototypes of the seats is not difficult, for the seats are types of chairs or armchairs. The human prototypes of many of the parts of a chair can at once be known from nomenclature. The back of a chair corresponds to the back of a person; and its seat corresponds to the seat of a person. The legs of the chair correspond to the legs of a person; and its arms correspond to the person's arms. The human prototypes of the parts of a chair can also be known at once from juxtapositions of human and mechanical parts. Thus, when a person sits on a chair, his back is against the back of the chair, revealing that the back of the chair forms a mechanical extension for the back of the person, supporting it and relieving it of some of its tasks, like that of the need for holding the trunk erect. The seat of the person is given an extension by means of the seat of the chair, and mechanical and human contrivances are in contact, and since they are in contact the mechanical contrivance must be derived from and must be an extension of the human contrivance (Rules 1, 3, and 7). When a person sits upright in an armless chair, the top of the back of the chair usually reaches about to his shoulders. If his arms are left unsupported, they will hang down, and the back legs of the chair will form prolongations of his arms or upper limbs. The lower parts of his legs will be alongside and parallel to the front legs of the chair. It seems therefore, curiously, that the front legs of a chair correspond to the legs of a person, and the back legs correspond to the person's arms; that is, the front legs of the chair correspond to his hind limbs or legs, and the back legs of the chair correspond to his front limbs or arms.

When several persons sit on a form, say one made from a

long board or plank and having four legs, two at each end, all their seats are given mechanical or artificial extensions by means of the board or plank, and all their legs mechanical or artificial extensions by means of the four legs of the form. The legs of the persons are not separately mechanized, and the four legs of the form have to serve as extensions of the legs of all the persons, and the legs of the form can be regarded as the mechanical extensions of all the human legs fused into four strong and thick mechanical legs. An ordinary board or plank, however, does not serve very well as an artificial extension of the seats of the persons, as it does not conform to their shapes. Better correspondence of human and artificial contrivances is obtained when the seat of the form is curved or shaped, or when cushions are placed on it, for the cushions easily conform to the shapes both of the board and the human seats. Greater comfort can also be obtained by providing the form with a back to support the human backs and relieve the persons of the need for holding their backs erect.

When a person sits correctly in an armchair, his forearms rest on the arms of the chair; and this reveals that the arms of the chair are mechanical extensions of human arms. This fact is also evident from nomenclature, the arms of the chair being named after the human arms. When in the chair the seat and arms of a person are horizontal, approximately; the back and legs and upper arms are vertical; and the directions of the human parts therefore correspond to those of their mechanical counterparts.

Most of the organs and parts of the skeleton of the motor car are in positions which correspond fairly well with the positions of similar organs and parts of the skeleton in a creature. The fore limbs of the motor car, represented by the spokes of the front wheel, are at the ends of the shoulder girdle, represented by the front axle; and the back limbs similarly are at the ends of the pelvic girdle. The backbone, represented by the transmission shaft, proceeds from the middle of the pelvic girdle, or back axle, towards the middle of the shoulder girdle, or front axle; and part of the

backbone is probably represented by the crank-shaft, the transmission shaft being an extension of the crank-shaft. The engine in early types of the motor car was usually behind the front axle; but more recently the axle has tended to come more under the engine, and the nostrils and mouth, represented by the openings of the carburettor, are sometimes in front of the shoulder girdle, as in a creature. The mechanical heart and stomach may be situated with respect to the front wheels and axle much as the head and stomach of an animal are situated with respect to its fore limbs and shoulder girdle. But since the engine is mainly above the line of the transmission shaft, that is above the line of the mechanical backbone, the heart and stomach of the motor car, at present, are above the backbone and not below it as in an animal.

The wheels of the motor car are coupled to the engine, and the power of the engine is directly transmitted to the wheels, by way of various mechanisms like gears and cranks. But the human engine, it seems, is not directly coupled to the locomotive machinery, and the human wheels, formed by the legs and feet, are driven only indirectly from power generated by the engine of the body. In this respect the human body can be compared, say, to a submarine whose engines are not directly coupled to the propellors, but charge electric batteries from which power is obtained to drive the propellors. The human body probably has power storing contrivances which are copied by such contrivances as electric storage batteries. It can be noticed that when a person is active the heart works harder than when he is at rest, probably because then the storage contrivances are releasing power more rapidly and need recharging at a greater rate.

CHAPTER 65

LINKS

THE gun, we have seen, has been assembled from weapons like the club, spear, sling, and bow and arrow; the internal combustion engine from contrivances like the bucket and windlass, the oil can, and the water pot above a fire. But the gun has not been made merely by placing the various earlier weapons together, but has been made by combining them. The internal combustion engine has not been made merely by placing the various earlier contrivances together, but has been made by combining them. Different contrivances are combined by means of links. Before two mechanical contrivances can be combined their link must be found. A study of links is essential to an understanding of the ways in which mechanical contrivances develop; but a full study cannot be made in this work. A few remarks however will be made, to indicate the nature and some of the characteristics of a link.

A study of the fountain pen or of the typewriter soon shows how different mechanical contrivances become combined, and gives much information about the nature of a link.

The self filling fountain pen is a contrivance in which an ordinary pen, an inkwell, and a filling device are combined. The penholder, or shaft of the pen, is hollowed out for use as a reservoir for the ink, and the inkwell is placed in the penholder. Before the self filling device was used, a separate filler had to be used. This consisted of a glass tube and a rubber bulb; and to fill the pen its end had to be unscrewed to receive the ink. It was later found possible to combine the filler with the pen and inkwell, by placing the filler inside the penholder or barrel of the pen, the filler of course being modified in form and materials to allow this to be done. It now usually consists of a rubber tube inside the barrel of the pen, and instead of squeezing the rubber bulb

with the fingers directly, the rubber bulb or tube is squeezed indirectly by means of the little lever placed at the side of the barrel of the pen. The cumbersome inkwell, the separate filler, and the ordinary pen, have now been combined in one contrivance; and the contrivance takes up little more room than an ordinary pen.

The inkwell could not be combined with the pen until means had been found of regulating the flow of ink from the inkwell to the nib. This regulation is effected when an ordinary pen and a separate inkwell are used by the writer dipping the nib in the ink when the nib begins to run dry, the ink being thus made to run more or less evenly from the inkwell to the nib and thence to the paper. In the fountain pen a small device called the feed bar, projects along the nib from the barrel and allows the ink to be fed from the barrel as needed, the device being operated by the pressure of the nib on the paper. The feed bar is the link which allows the inkwell to be combined with the pen. The small lever in the side of the barrel is the link which allows the self filler and inkwell to be combined.

The author has not made a study of writing implements; but it is easy to see that the human prototype of the nib is a finger nail. When using an ordinary pen, the forefinger is placed on the holder near the upper or broad end of the nib; and the nib acts as a mechanical extension of the nail. The nail, since it is not near the point of the nib but is at its upper end, is in a transferred position, being transferred from the paper to the upper end of the nib (Rule 8). All movements of the nib and nail are similar, the finger nail and the nib even going to and from the inkwell together when the nib is being replenished with ink. The pressure of the nib on the paper depends on and is proportional to the pressure of the fingers; and it is really the fingers which press on the paper, indirectly of course through the agency of the nib (Rules 4 and 5). The nib by itself of course cannot press on the paper or perform any writing actions. The flow of ink to the paper is therefore regulated by the pressure of the fingers on the upper end of the nib.

The finger nail is not placed directly on the nib or penholder, for the part of the finger underlying the nail is between the nail and the nib or penholder. This device, formed by the part of the finger under the nail, corresponds to and is the human prototype of the feed bar of a fountain pen. As a person writes with an ordinary pen the human feed bar moves slightly and continually with respect to the nail, in much the same way as the mechanical feed bar of a fountain pen moves slightly and continually with respect to the nib. When a person writes with a fountain pen, the human feed bar and the mechanical feed bar work together and perform similar actions. These actions can easily be seen as a person writes. The feed bar of the fountain pen machine is therefore in two main parts, a human part being formed by the part of the finger under the nail and a mechanical part being formed by the part of the finger of the fountain pen under its nail, or nib.

By means of the nib of a quill or ordinary pen or fountain pen the human nail is released from the task of making contact with the paper and from the need for being dipped in the ink. The nail however is occasionally used as the nib. Dr. G. M. Humphry writes thus of the method of using the nail as a nib: — "The Dervishes in some parts of Asia allow the thumb-nail to grow long, and then pare it to a point, so as to be able to write with it. Dr. Wolff, the Eastern traveller, has told me he has repeatedly seen this done, and that he has in his possession manuscripts written in this way." [1]

The finger is given several mechanical extensions by means of the levers of a typewriter key; and the finger makes contact with the paper only indirectly by means of the key and its levers and the type bar. Typewriters formerly had two keyboards, one for small letters and one for capital letters. But the link of the shift key was discovered; and the discovery allowed the capital and the small letter to be placed on the same type bar. With the shift key, one keyboard only is now needed to print capital and small letters.

[1] *The Human Foot and the Human Hand.*

A typewriter with two keyboards consists of two contrivances placed together without being combined. When a shift key is used, the two contrivances are combined, with a saving of space and parts. One entire keyboard with its complicated parts is dispensed with; and the combined machine occupies little or no more space than either a machine for printing capitals or one for printing small letters would do by itself.

It is necessary to distinguish between machines made by combining contrivances and those made by adding or placing contrivances together. When contrivances are added, there is an increased complication of parts and devices. When contrivances are combined, there is a saving of parts and space and a simplification and greater ease in operation. Thus, the typewriter with a shift key has fewer parts than one with a double set of keys; and it is more easily operated, for the typist's hands can remain almost stationary, and touch typing is easier. Two contrivances added together are however more impressive than when combined. Thus a typewriter with a double keyboard is likely to impress people's minds with a sense of its maker's cleverness much more than the better and simpler typewriter with a single keyboard.

Many other links can be seen on typewriters. It is desirable when typewriting to be able to draw lines. A separate contrivance could be added to the machine to allow this to be done; but it has been seen that by using the dash sign continuously lines can be drawn without the need for a separate line drawing contrivance, and so one key can serve two purposes. The dash key is a combined device, for it can be used for drawing a line or for printing a dash sign. The link is formed by making the dash sign just long enough, so that when the next dash is printed it links up with the previous one and a continuous line is made.

Again, it is useful to be able to print rows of dots; but additional mechanisms can be made unnecessary by repeating the full stop sign. The full stop key is therefore a combined device, because it can be used for printing a full stop and it can also be used for printing a row of dots.

The small letter l and the capital letter O can be used to print the numbers one and nought respectively; and two keys can be saved. These two letters are therefore combined devices. The links are formed by making the numbers and the letters in such a way that the number or letter can be used without distinction, and so that it is impossible to see whether a letter or a number is printed.

Two contrivances are sometimes combined in such a way that their link is lost to sight. The link, for example, between the device on a typewriter that prints a full stop and the device that prints a row of dots is lost to sight. It is therefore often difficult when contrivances are combined to realize that there is more than one contrivance. A person beginning to use a typewriter, for example, imagines some parts are missing. He searches in vain for devices for drawing a line, for making a row of dots, for printing the figures one and nought, and so on. The devices are all on the typewriter, but combining devices and parts has made them at first difficult to discover. An uninstructed person similarly might fail when looking at a bow and arrow to see a club or spear or sling in it. But as has been shown, these weapons are all combined in the bow and arrow.

A link has essential features of the two contrivances it unites or combines. This can be seen by studying for example a window pane or a floor of a lift. A window pane forms the link between the inside of a room and the outside world. The walls separate the inmates of a room from the outside world; but the window pane unites them to it. It can form a link because it has certain essential features or properties both of the walls and of the outside air. Like the wall it is rigid, excludes the air, resists the passage of noise, and so on. It has also the essential feature of the air of transparency, allowing the people inside the room to see through the parts of the wall formed by the window pane, and so to unite themselves to the world outside. The window pane also forms a link between the light outside and the light within the room.

The floor of a lift can, at the operator's will, form part of

any floor of the building; and so if the passenger stands on it he can be transferred from any floor to any other (Cp. Rule 8).

A wheel forms the link between the ground and the carriage. To form the link some part of the wheel must be stationary because the ground is stationary, and some part must move at the same rate as the carriage whatever its velocity. By elementary mechanics, the part of the wheel in contact with the ground is momentarily at rest and does not move forwards or backwards. The axle moves always at the same rate as the carriage. The wheel therefore can act as a link between the stationary ground and the moving body of the carriage.

A bridge is the link between two banks; for at each end it becomes part of the land at that end. It can act as a link also between a road or railway system on one side of a river and a road or railway system on the other side. After the bridge is made the two systems become one; and if two railway systems are linked a common time table becomes possible and necessary.

Some other links will be pointed out. The reader will be able to see that the link always partakes of the natures of the two contrivances it unites, and that its use results in a saving of parts and space and gives other advantages.

A canal can link a sea and a river; and can partake of the natures of the sea and of the river. At one end of the canal the water is fresh, and at the other end salty. A lock of a canal links canals at different levels; and before this link was discovered it was not possible to combine waterways of different levels. Ball and roller bearings form links between two surfaces, and allow them to be combined, and actions between them to be transmitted at right angles to each other. A film of oil links two surfaces somewhat similarly. The bolt of a pair of scissors allows two knives to be combined. The bucket of a water wheel links the water and the wheel, and moves at the same rate as the water and as the circumference of the wheel. It becomes part of the running water system since it holds part of the running water, and is part

of the wheel. The rod of a door hinge is the link which enables a door to form a closed or open room. Mortar or cement is the link which unites bricks or stones, and partakes of the natures of both surfaces simultaneously. A pulley or lever can act as a link between forces acting in different directions. A chimney forms a link between the fire and the atmosphere. At its lower end the bricks become as hot as the fire, at the top end the vent leads the gases into the atmosphere. The hole in the bottom of a flower pot is the link between the plant and the earth. The pendulum of a clock acts as a link between time and length. The column of mercury in a barometer is a link between pressure and length. A letter forms a mechanical link between the thoughts of the writer and the receiver of the letter. A telephone wire is the link between the ear and speech mechanisms at one end and similar mechanisms at the other. The link of a chain, as its name shows, links different parts of the chain. The reader will quickly see a thousand and one other links.

To discover the link between two contrivances is a matter of much importance, and when the link has been discovered development of the machine formed from the two contrivances is rapid for a time. No link can be discovered until the two contrivances have been developed separately to the limits possible. The discovery of the link is then inevitable.

Nature uses links. The stalk is the link which unites the leaf or flower or fruit to the branch. At one end the stalk becomes part of the leaf or flower or fruit, and at the other it becomes part of the branch. The ball joint acts as a link between two limbs. Synovial fluid forms the link to join the two surfaces of a ball joint. And so on.

A few examples of contrivances which are merely added will now be given, to illustrate essential differences between combined and added contrivances.

The tool bag on a bicycle is added to the bicycle, but is not combined with its mechanisms, and is merely suspended from the saddle. The oil can placed in a hole in the butt of an army rifle is not combined with its mechanisms, and is merely added to the rifle. The strap or chain of a watch is

not part of the watch's mechanisms, and is merely added to the watch. A gun placed on a railway truck or motor lorry is not combined with the locomotive devices formed by the wheels of the truck, and is merely added to the truck or lorry. A mechanical man, or robot, usually consists of a number of added contrivances which are not combined. And so on.

Mechanical and human parts of an offensive machine are combined when a weapon is being wielded. The links between human and mechanical parts are however difficult to discover, because so many devices are formed where they join. When, for example, the hands close round the shaft of a thrusting spear, they form a barrel, clasps, elevating and depressing devices, directional devices, sights, and very many other devices; and it is difficult to discover the link between any particular mechanical and human part. But when human links become mechanized and externalized they can be seen and studied. Thus, for example, the link which allows the lower arm to move relatively to the upper arm is formed by the elbow joint. This joint or link is partly mechanized and externalized in, say, the joint where the handle and thong of a war flail meet, and this mechanical joint can be studied.

When a rider is astride his bicycle, his locomotive mechanisms and balancing mechanisms are combined with those of the bicycle, and are not merely added to them. The mechanisms of the internal combustion engine have been fairly well combined with locomotive contrivances; and in a motor car the engine is combined with the wheels by such links as levers, ball joints, chains, chain wheels, and gear wheels. But offensive mechanisms have not yet been combined with much success with engine or locomotive contrivances. But attempts have been made to combine them. A gun placed in or on a tank is usually merely added to the tank and not combined with its engine or wheels. But possibly when say the gun of a tank is controlled by gyroscopic or other devices so that it always points at the target however the tank moves, some mechanisms of the gun are then combined with those of the tank. The offensive mechanisms of a creature of course are perfectly combined with its engine, locomotive, sight,

hearing, scent, growth, and all other mechanisms. Probably, in time, the different types of mechanical machines will all be combined; and one day there may be a mechanical creature possessed of reproductive, offensive, engine, locomotive, optical, vocal, scent, auditory, and many other contrivances, all working in harmony.

But the mechanisms of such a creature will still be correlated to mechanisms of the body, and the creature will still not be capable of actions independently of the body. Its sympathetic mechanisms will perhaps appear to give it an independent existence; but no mechanical creature will become possessed of life properties independently of the human body. But development of machines probably will proceed, in the very distant future, so far that a creature may be produced that will seem to be independent of the body; and one day no doubt machines will behave somewhat like birds or other creatures, which seem to be independent of the mechanisms of the human body.

Chapter 66

GENERAL REMARKS

IT has been pointed out that a mechanical weapon becomes an integral part of the offensive machine when it is fitted to the body, and enters into organic relationships with the offensive machinery. A study of weapons shows that when a mechanical contrivance is being operated by the body, its parts work with their human counterparts, and perform actions for them. A part of the machine is not then formed by the human part or by the mechanical part, but by the human and mechanical parts together, and the human and mechanical parts form an organic unity.

The process of developing weapons may be described as a process of reproducing more parts and devices of the human offensive machinery in mechanical forms. At first, one or two parts only of the human offensive machinery are reproduced, and those very crudely. Gradually, more parts are reproduced, and some already reproduced are made less crudely. Very simple copies of a few parts of the human machinery in time give place to better copies and to copies of more parts. Similarly the process of developing any class of mechanical contrivances may be described as a process of reproducing more parts and devices of some machine of the body

When parts of a machine of the body are mechanized and made to exist outside the body, they reproduce the arrangements, materials, actions, and other features of their human counterparts very imperfectly; but nevertheless the external parts of the machine are organized as their human counterparts are organized, and when being used become integral parts of the machine of the body and enter into organic relationships with it. As the process of mechanization continues, the organization of the external parts corresponds more closely with that of their human counterparts. Since

correspondence of organization, materials, and actions, is brought nearer as mechanization proceeds, gradually machines will come to possess features and properties we associate with organic life. Therefore by making weapons or other mechanical instruments or machines man organizes materials to possess the property of life. Since the property of life is not given at any definite stage of development, it must be possessed by the most elementary mechanical contrivance, when it is being operated by the body; and the degree of life possessed by a mechanical contrivance is thus proportional to the degree of development of the contrivance.

When the mechanical contrivance is not being operated by the body it does not possess any life. It must however be remembered that a mechanical contrivance, the internal combustion engine for example, can be operated by the body when the body is far away from it. But a simple mechanical contrivance like a club, which has no mechanical nerves, has no life when not being wielded. It is then merely a piece of material, and has neither use nor meaning.

It is not known how long a time has elapsed since man first made a mechanical contrivance; and it is only recently that mechanical contrivances have developed so much that it is no longer possible to fail to see that machines of the body are being reproduced by them. But even in the most complex and developed weapons or other machines of the present day the organization of life is very poor. The internal combustion engine, for example, although it can easily be seen to have respiratory organs, a heart, an alimentary canal, a double nervous system, and some other organs, has the organs and nervous systems very poorly developed compared with those of creatures. An immense period of time must elapse before any machine can be brought to complete correspondence to any of nature's machines.

It is evident therefore that the credit for discovering how to make organic life belongs to the man who made the first mechanical contrivance. By making it he reproduced parts of the body, and when using it gave it some of the properties of the life of his body. Those who imagine the secret of

organic life can be obtained by laboratory methods, say by making a living cell, are in the tradition of the alchemists and of those who tried to make perpetual motion machines. Man can discover the secret of full organic life only by developing machines until they possess full organic life.

Weapons develop by a process which is somewhat analogous to the process of growth, and is probably a copy of it. When the first weapons were made, one or two parts of the human offensive machinery appeared outside the body, emanating from it as a type of growth. As new weapons were made, other parts appeared as further extensions or growths of parts of the machine. This process will continue indefinitely as new types of weapons are made; and the secrets of organic growth will become revealed as weapons and other mechanical contrivances are developed. The ways in which the processes of growth are copied as more parts of the machine are externalized and older types of weapons are replaced have not been stressed in this work; but no doubt the reader will have noticed similarities between the processes.

Clearly, the goal or end to which the makers of weapons is directed is to reproduce the offensive and reproductive machinery completely; of the makers of the internal combustion engine to reproduce the engine of the body completely; of the makers of locomotive contrivances to reproduce the locomotive contrivances of the body completely. A study of other classes of mechanical instruments, contrivances, and machines, would show that the goal of the makers of optical instruments is to reproduce the vision machinery of the body, of the makers of chronological instruments the time keeping machinery, of the makers of acoustic instruments the hearing machinery, and of the makers of aircraft the flight machinery of the body; and so on. Presumably, if man could mechanize all the machines of his body and combine them the result, as has been stated, would be man. Man's mechanical contrivances, however, at present are in very rudimentary stages of development, and he has made but little progress towards this goal.

By studying mechanical contrivances with reference to the body it is possible to know the meaning of man's industrial activities, the goal of the makers of machines, the ways mechanical contrivances have originated and developed, the ways new types will originate, and the ways the different types of mechanical contrivances are related to each other. More important still, the study provides an easy and powerful means of obtaining knowledge of the construction and working of the machines of the bodies of creatures. It shows the human body has the peculiar property or power of reproducing parts of itself as mechanical embryos or growths, without man's design and it seems hitherto without his comprehension, with man as an unconscious agent in effecting nature's purposes, man while effecting her purposes fondly imagining himself the inventor of the mechanical contrivances. It shows also that mechanical contrivances are rudimentary creatures.

It should be noticed that even if mechanical contrivances were studied without reference to the machinery of the body, it would still be necessary to regard them as rudimentary types of mechanical creatures. Thus, if we studied a motor car without reference to the body, it would still be possible to discover it has organs similar to those possessed by creatures. It could be seen that the engine has an alimentary canal, respiratory organs, heart, stomach, and many other organs corresponding to those of creatures; that the body of the motor car has a type of vertebrate frame, with a backbone represented by the crank shaft, power shaft, and propellor shaft, and vertebrae represented by gear box cogs. At the front the frame would be seen to diverge into two limbs, and at the rear into two other limbs, which performed rudimentary locomotive movements. The extremities of the limbs would be types of hands or feet, and wrists and ankles and palms and fingers and toes would all be represented. The various parts of the motor car would be in positions not very different from corresponding parts in creatures. The motor car could be seen to have a fairly well developed nervous

system, with a ganglion, or nervous centre, formed by the magneto. A comparison of early and later types of the motor car would show that as the machine developes it comes into closer correspondence to the body of a creature. It would therefore be necessary, even without any acceptance of the human prototype theory, to regard it as a creature.

But it would be noticed that although the motor car has well developed engine and locomotive organs and fairly well developed optic organs, it possesses no auditory, vocal, self-repair, clothing, or other organs except engine and locomotive and optic organs. It is true traces of some of these other organs could be found. For example, a rudimentary vocal organ would be seen to be reproduced by the horn; but no mechanisms could be found for starting it. A few rudimentary organs of touch could be found, one for example being formed by the self starter button, and if this were pressed actions would follow; but again no mechanisms would be found for pressing this organ of touch. It would be difficult to discover the use of the tool box and its implements. But careful study would show that the tools fitted various nuts and bolts and other parts; and a guess could be hazarded that the tools had something to do with the creature's self repair or adjusting mechanisms. This could be seen to be the case, because occasionally some bolt or nut would be seen to be replaced or tightened. No outside agency could be seen performing these actions, because we should not admit the human body is in any way related to or connected to the motor car.

A study of a gun would show that it possesses well developed offensive and reproductive organs; but no other organs would be much in evidence, although traces of some would be discovered. Rudimentary optic organs, for example, would be seen in the telescopic sights of rifles or in the range finders of naval guns.

A study of other mechanical creatures would show that each type reproduces mainly only one or two types of human machines, and that parts of other machines are either wanting or in very rudimentary stages of development.

These circumstances would however be paralleled fairly well in creatures. Organs and mechanisms which are well developed in some creatures appear to be wanting or in very rudimentary stages of development in others. For example, in birds the flight mechanisms are very well developed, but in man and most other creatures are almost atrophied or undeveloped. Or again, in man the lungs are well developed, but only traces of gills can be found; the opposite is the case in fishes. A host of other examples will occur to the reader. A study of mechanical creatures therefore would show that the different types develop in somewhat the same ways as different types of creatures develop; and the picture of the development of mechanical creatures is perhaps also a picture of the development of living creatures. But from our knowledge of the human prototype theory we know mechanical creatures are related to the body and the theory gives us powers of discovering how they are so related; and by studying the mechanical creatures with reference to the body it may therefore be possible to discover how living creatures are related to man.

The reader will have noticed that the study of the power machinery has been made in a somewhat different way from the way the study of the offensive or locomotive machine was made. The study of the offensive machine was made by studying first simple types of weapons; and similarly the study of locomotive contrivances was begun with the study of simple locomotive devices. But the study of the power machine was begun with the study of the internal combustion engine; and only a very few of the many contrivances from which it has been derived have been studied.

There are advantages and disadvantages in both methods of study. A study of the offensive machine begun by studying the gun would soon allow the human counterparts of many parts of the gun to be known; and this would make it an easy matter to identify human counterparts of the weapons from which it has been derived. But since many parts of the gun are in transferred positions, difficulties would be found, until simpler weapons had been studied, in discovering

how each part of the gun works with its human counterpart.

By beginning the study of the power machinery with a study of the internal combustion engine, the human counterparts of many of its mechanisms as we have seen can soon be discovered. But difficulties are then experienced in discovering how the various mechanisms are correlated to and work with their human counterparts. It is true that having discovered some Rules describing how parts of mechanical contrivances can be transferred, it is possible with some careful study to see why some parts of the engine are in their present positions. But the more satisfactory and surer method would be to study all the mechanical contrivances from which the engine has been developed; and by tracing their developments to see how the various parts and devices of the engine have arrived in their present positions. But a great deal of research would be needed to discover and study all the contrivances from which the engine has been developed. A few only of these are known to and have been studied by the author; and the fuller study must be left to his readers. A vast field of research, promising many important discoveries, awaits exploration by anyone who will diligently study these contrivances, and its exploration will probably present few difficulties.

Any class of mechanical contrivances can be studied by either of the methods used in this work, although for a complete study both methods would have to be used. A study of some classes might be easier by one method and of others by the other method. For example, a study of the submarine would perhaps be easiest by studying first the submarine, and afterwards the various contrivances from which it has been derived. No difficulty would be found in identifying counterparts of most of the parts of the submarine; but as it is obviously related in many ways more closely to the fish's body than to the human body, it might be necessary to relate its parts first to parts of a fish's body and then later to parts of the human body. Or again, parts of an aeroplane can at once be related to parts of the flight machinery of a bird. Indeed a child could see that its wings, for example,

correspond to the wings of a bird, its body corresponds to the body of the bird, its rudder and tail correspond to the tail of the bird; and so on. A study of optical instruments, however, could probably best be made by studying first simple optical instruments like lenses, spectacles, and telescopes; and later more complicated vision contrivances like cameras, and television apparatuses.

When studying mechanical contrivances with reference to the body a new branch of scientific study comes into existence. This study can conveniently be called mechanical biology. Mechanical biology is therefore the study of the relationships of mechanical contrivances to the body. The body is a very complex organism which cannot easily be studied directly; but it is a comparatively easy matter to study it indirectly by studying mechanical contrivances, for all mechanical contrivances are elementary models of parts of machines of the body.

The theory that mechanical contrivances are similar to contrivances of the body is not new; for it is commonly accepted that there are correspondences of shapes, materials, and actions, of mechanical and human contrivances. Nearly every writer on the biology of the body relates human and mechanical contrivances. Few omit to point out, for example, that the lens of the eye and an optical lens resemble each other; that the eye and a camera are constructed on similar principles; that a nerve of the body and an insulated electric wire have many features in common; that the heart and a pump have similar actions; and so on. Whole books have been written by biologists and others to show correspondences between human and mechanical contrivances. No new theory is therefore advanced when correspondences between human and mechanical contrivances are shown; and the theory that human and mechanical contrivances always work together represents but a small advance in thought.

But the realization that human and mechanical contrivances always work in harmony allows a new world of knowledge or learning to be discovered; and the way to this new world is shown in this book.

The main purpose of this book is not to describe the new world in detail or even in outline. To give a description of a new world or continent is a task beyond the powers of the person who first sights its shores. The object of this work is to show others that the new world exists and to show the way to it; and the task of mapping its outline and discovering its details must be left to others who will follow.

The author has seen no more than a fragment of the fringes of the vast new world of knowledge; and has visited only a few islands lying off its mainland. The island of weapons has been mapped in this work perhaps sufficiently well to show its main features and some of its details. The island of locomotive contrivances has been briefly described, but most of its features remain to be discovered. The island of engine mechanisms has been hastily surveyed. The maps of these islands will inevitably be found to be fragmentary, to have many errors, and indeed perhaps to be misleading in many ways; and although this work shows the way to the new world of knowledge and gives a picture of small fragments of it, no more dependence should be placed on its details than would be placed on the details of a map of a new continent or world hastily made by the first person who had sighted its shores. The author has tried to avoid errors, but no doubt it will be found he has sometimes described an island as a peninsula, a peninsula as an island, a river mouth as a gulf, and probably has made worse errors. But the maps can easily be corrected by those who will follow.

In exploring new lands the first to arrive on its coasts can hardly help making discoveries which may be the envy of succeeding generations of explorers. To make discoveries in the old world of knowledge is becoming difficult. But exploration of the new world of knowledge offers prizes as great as those offered to the explorers of America in the fifteenth and sixteenth centuries.

Conditions in the search for new knowledge today curiously resemble those which existed about the end of the fifteenth century in the search for new lands. Then, men were active in exploring the old world; and formed their

ideas and theories about the shape of the world without realizing a new world existed or that the world is a globe which can be circumnavigated. The human prototype theory now allows a new world of learning to be reached and explored, and perhaps in due time will allow the shape of the world of learning to be known.

The author, in a previous work, pointed out that rules or conditions in one type of game are often found exactly reversed in another type. Conditions when exploring a new field of learning and when exploring a new land similarly are in some respects reversed; for he who would try and discover some new country must persuade others of its probable existence before he can proceed thither. Conversely, he who discovers a new field of learning must afterwards try and convince others he has discovered it. Thus, for example, Columbus had to spend many weary years trying to persuade men that land could be reached by sailing to the west, and had to meet with prejudice, ridicule, and unbelief, before he could proceed to prove his theories. But when he had reached the shores in the west, the ridicule and unbelief of his opponents were turned to their shame. Conversely, when for example Galileo announced that the earth moves, he had then to meet with ridicule and persecution. The author, having discovered new realms of knowledge has now to convince others of the existence of these new realms, and probably, if tradition counts for anything, must meet ridicule, unbelief, and persecution. Indeed he has already met with a good deal of ridicule and unbelief; but the importance of his discoveries no doubt merits much more ridicule, more profound unbelief, and more bitter persecution than has yet been met with. But truth is great and will prevail; and no Councils of Salamanca or ridicule or unbelief can prevent its triumph and the confusion of its opponents.

As stirring times await the pioneers of the new world of knowledge as awaited the fifteenth and sixteenth century explorers of America. The new continent of knowledge probably stretches from one pole of knowledge to the other. Its coasts must be explored. Entry must be found into the

Pacific of learning, and its seas must be crossed so that perhaps the limits of man's knowledge can be known. Ancient and powerful civilizations of the mind founded on ignorance and wrong thinking must be met, and battles against fearful odds must be fought. Curious articles and new products wait to be discovered and brought to the knowledge of men's minds. Who can say what will be the results when the products and treasures and extent of the new world of learning are discovered? High adventure and great glory are offered to all with courage enough to venture to this new world. Come, Cabral, Balbao, Cabot, and Ojeda, of the new age, make your adventurous voyages! Come, Amerigo Vespucci, give your name to the new continent! Come, brave Cortes and Pizarro, win your great empires! Come, Raleigh, found your colonies! Come, gallant conquistadores, use your courage and reckless daring in the new world! Come, Drake and Magellan, cross the great Pacific and circumnavigate the world of learning! Come, Frobisher and Hudson, penetrate the eternal snows of the north! Come, de Soto and Orellana, launch yourselves on the Mississippi and the Amazon, and reveal mighty highways through the great plains of the new world of learning! Come, Pilgrim Fathers, pioneers, and frontiersmen, leave the old world of shibboleths and warped philosophies, and find freedom for your minds in the vast new world. Once again, the cry is Westward Ho!

INDEX